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MODEL 5510

UNIVERSAL COUNTER AND TIMER

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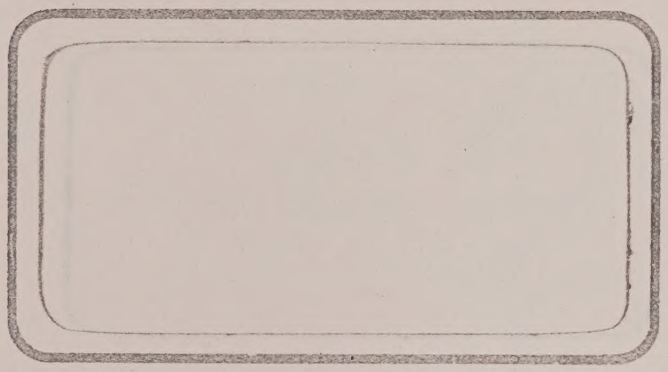

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ANALOG COMPUTERS

Berkeley *division*

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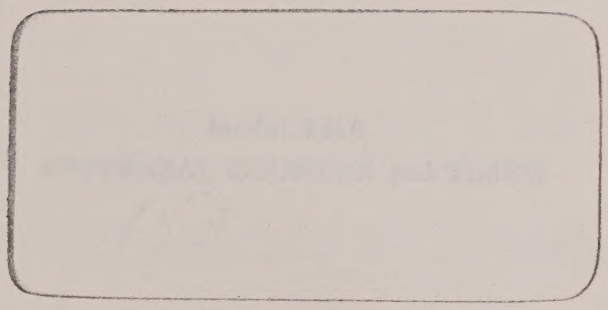

WARNING

Do not attempt to operate this instrument until you have read the Instruction Manual.

INSTRUCTION
MANUAL

Lot 8 and up
Serial 315 and up

Model 5510
UNIVERSAL COUNTER and TIMER

Lost

BERKELEY division of
Beckman Instruments, Inc.

Richmond 3, California
20 November 1954

WARRANTY

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Instruments to be repaired must be returned to the factory with transportation charges prepaid. Repair work will be performed only upon receipt of a written purchase order or authorization.

Claims for damage in shipment should be filed promptly with the transportation company. All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate.

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing.

Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, BERKELEY division of Beckman Instruments, Inc., Richmond 4, California.

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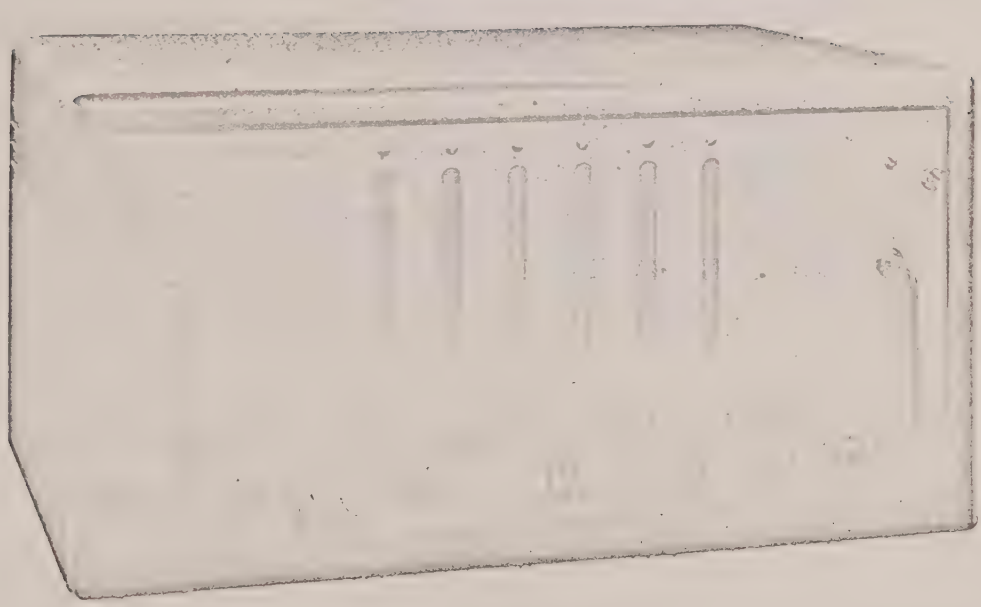


Figure 1 Model 5510 Universal Counter and Timer

1 Introduction

DESCRIPTION

The Model 5510 Universal Counter and Timer is an accurate high-speed electronic counting instrument designed to measure the characteristics of electrical, optical, or physical events relative to time. Discrete events of either random or regular distribution may be counted for a precise time interval. The elapsed time between any two events or the period of frequencies may be measured with the time displayed directly by the lighted Decimal Counting Units (DCU's).

Various transducers such as photocells, magnetic pickups and switches may be used to translate the event into the proper input form. Because of its versatility, the Universal Counter and Timer is ideal for rapid and precise measurements in numerous applications. Among them are: relay and switch timing, viscosity determination, ballistics measurements, tachometry, determination of frequency ratio, phase measurements, use as a secondary frequency standard, and telemetering.

SPECIFICATIONS

COUNT Operation

Range	DC to 1,000,000 cps
Input Sensitivity	0.2 v. rms
Capacity	1,000,000 counts

EPUT Operation (Events-Per-Unit-Time measurement)

Range	DC to 1,000,000 cps
Input Sensitivity	0.2 volts rms
Accuracy	±1 count, ± crystal stability
Stability	1 part in 10^6 (oven crystal)
Gate Time	0.00001, 0.0001, 0.001, 0.01, .1, 1, 10 seconds
Self-checking	Direct test of all dividers and control circuitry

Input Impedance	10 megohm shunted by 35 $\mu\mu$f

TIM Operation (Time-Interval-Meter)

Range	3 μsec. to 1,000,000 seconds
Accuracy	±1 count ±crystal stability
Input Sensitivity	1 volt peak-to-peak, direct-coupled to amplifier
Unit of Time Measurement	1 μsec. to 10 sec. by powers of 10
Input Impedance	10 megohm shunted by 35 $\mu\mu$f

PERIOD Measurement (Period of wave, pulse width or spacing measurement)

Range	10 μsec. to 1,000,000 seconds
Input Sensitivity	1 volt peak-to-peak, direct-coupled to amplifier
Unit of Time Measurement	1 μsec. to 1 sec. by powers of 10
Gate Time	1 cycle or 10 cycles of input signal
Accuracy	±1 count ±crystal stability
Input Impedance	10 megohm shunted by 35 $\mu\mu$f

General

Display Time	Continuously variable from 0.2 to 5 seconds
Power Input	117 volts, ±10%, 50-60 cps, 400 watts
Accessory Socket Connections	Miniature rectangular socket Model 1452 Digital Printer
Dimensions	20 3/4" wide x 10" high x 15" deep

ACCESSORIES

The Berkeley Model 1452 Digital Recorder, designed for use with the Model 5510 Universal Counter and Timer, provides a means of converting count information into printed form. The unit will print the count accumulated by the Model 5510 during each of its counting periods. The printed count appears sequentially in Arabic numerals on a standard adding machine tape. The Digital Recorder is ideal for long-term stability checks, recording transcients or for making a permanent printed record in digital control systems.

The Model 1440 Series, Data Reduction Converters, convert digital information from the Model 5510 to a form suitable for recording on an IBM summary punch or an electric typewriter. The Model 1440S is designed for use with the IBM Summary Punch Type 523; the Model 1441S, for use with the IBM Summary Punch Type 615, and the Model 1442S, for use with an electric typewriter.

2 Operation

INSTALLATION

The Model 5510 requires no special installation procedure. It may be operated in any well ventilated location. The unit is designed to operate from an a-c source of 117 volts, 50-60 cps. at a power rating of 400 watts. Satisfactory operation may be obtained from power sources ranging from 105 to 130 volts.

CONTROL AND CONNECTOR FUNCTIONS

Front Panel

Input Adjustments (Attenuation, TRIGGER LEVEL & POLARITY controls)

All three TRIGGER LEVEL and attenuation controls operate in the same way. Each is associated with the adjacent input channel. The inner of the two concentric knobs is the TRIGGER LEVEL control. The outer knob is the attenuation control. Each of the two POLARITY switches is associated with the nearest input channel EXCEPT WHEN THE FUNCTION SWITCH IS SET AT THE PERIOD OR X/Y POSITION. At these two positions both POLARITY switches are associated with the Y INPUT channel.

The attenuator controls the level of input signal before it reaches any other part of the input channel. When the DC or the AC point on the attenuation control is set at one of the attenuation factors on the circumference (1, 3, 10, 30, 100 or 300), the input voltage is divided by that factor. When the DC point is at a factor, the total input signal is attenuated and passed to the input channel. When the AC point is at a factor the DC component is removed and the AC component of the input signal is attenuated and passed on. For reliable operation, the input signal amplitude measured in volts from peak-to-ground should not exeed TWICE the attenuation FACTOR to which the attenuation control is set.

The proper input adjustment is determined by nature of the input signal and the measurement to be made. To make an appropriate adjustment it is desirable to understand the effect of the POLARITY and TRIGGER LEVEL controls on the output of the input amplifiers. The input amplifiers generate a sharp pulse each time the attenuated signal passes in a given direction through a certain threshold voltage known as the "trigger level." (See Figure 2). When the associated POLARITY switch is set at "+", only pulses generated by excursions through the trigger level in a positive direction are passed to the succeeding circuitry. When the POLARITY switch is set at "-" only pulses generated by negative excursions are passed to the succeeding circuitry. During PERIOD or X/Y measurements, the switch nearest the Y INPUT determines the start-trigger polarity and the other switch the stop-trigger polarity. The X channel is not provided with a polarity switch and is wired to pass pulses produced by positive going

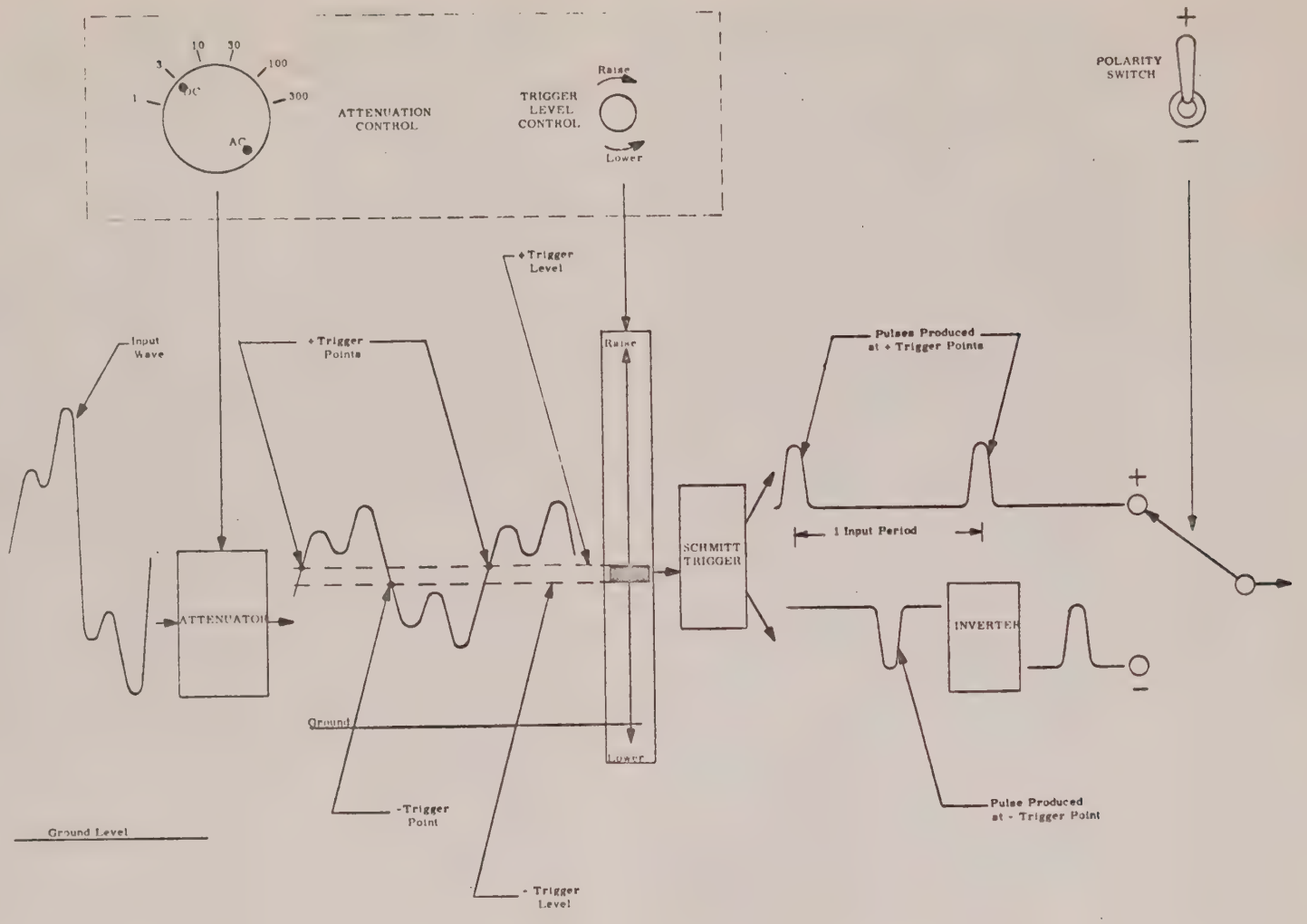


Figure 2 Effect of Input Controls

excursions only. The trigger level, when the signal is moving in a negative direction, is about 0.2 volt lower than the trigger level when the signal is moving positive.

The TRIGGER LEVEL control adjusts the trigger level of the attenuated signal. the level may be varied continuously from about -10 to +10 volts in the X amplifier and from about -4 to +3 volts in the Y and STOP amplifiers. Rotating the TRIGGER LEVEL control CLOCKWISE moves the trigger level from - to +. The best adjustment procedure is to visualize the shape, amplitude and distance from ground of the attenuated wave and to set the trigger level at the point on the wave where the most reliable pulse output may be expected. Examination of the input wave shown in Figure 2 will reveal that the trigger level may be set so far negative or positive that the wave will never intersect the triggering point. In this case no output pulses will be produced. If the trigger level is set near the lower of the two peaks, two pulses may be produced during each complete cycle. The trigger level setting shown in approximately correct for this waveform. The trigger level should be adjusted to the point on the input wave where extraneous variations in the input voltage (hum, noise, drift) are least likely to add or subtract output pulses or affect the time at which a pulse occurs. This point will generally be on a steep slope of the wave about halfway between the positive and negative peaks. When using any regular periodic input signal, consistent frequency or period readings are the best indication that the trigger level is properly located.

To set the triggering point on the input wave at a precise voltage apply a DC voltage of that value at the INPUT jack, place the DC point on the attenuation control at the appropriate setting and rotate the TRIGGER LEVEL control to the point where an output pulse is produced. With no input voltage the INPUT jack lies at ground and a pulse will be produced at ground level. Output pulses from the X channel may be seen as being counted when the FUNCTION switch is in the EPUT position. Pulses from the Y channel start and stop counting of time base pulses when the FUNCTION switch is at PERIOD. Pulses from the STOP Amplifier appear as stop signals with the FUNCTION switch at TIM.

Some information about the position of the trigger level relative to the signal may be extracted from the instrument itself. The trigger level may be varied between the positive and negative peaks of an attenuated signal whose peaks lie within the range of possible level settings. As the trigger level passes beyond the signal peak the pulse output of the channel will cease. This TRIGGER LEVEL control position should be noted.

POWER switch

Applies line voltage to the instrument when in the ON position as indicated by the green pilot light.

FUNCTION switch

Selects the function the instrument is to perform.

MULTIPLIER switch

Selects the time interval for events-per-unit-time measurements or the unit of time measurement for PERIOD or TIM use. The switch is calibrated in both cycles per second time base frequency and seconds per cycle time base period.

DISPLAY TIME control

Determines how long the instrument will hold its previous reading before recycling and beginning another count. When this control is turned to the extreme clockwise position and the switch clicks, the instrument will hold a reading until the manual RESET button is depressed.

RESET button

Removes the previous reading and readies the instrument to begin another counting period.

COUNT switch

Affects the instrument only when the FUNCTION switch is in the COUNT position. (See "COUNT" Operation" below).

Rear of Chassis

All the controls on the chassis rear are discussed in the maintenance section of this manual under "Routine Adjustments".

SCOPE jack

Connected to the suppressor grid of the signal gate tube. Makes the open-close signal available for examination on an oscilloscope.

TIME BASE OUTPUT

Makes the time base signal selected by the MULTIPLIER switch available for external use. Excessive loading of this output may prevent the instrument from functioning properly.

FUSES F401 and F402

Protect the instrument from overload. Located before the POWER switch on each side of the power line.

POWER IN 117V AC socket

Connects instrument to the power cord.

DIGITAL RECORDER socket

Provides connections to the Berkeley Model 1452 Digital Recorder and other BERKELEY data processing instruments.

OPERATING PROCEDURES

TEST Operation

To put the instrument in operating connect the power cord and turn on the POWER switch. After a two minute warm-up, test the instrument for proper operation:

1. Turn DISPLAY TIME to a point near the extreme counter-clockwise position to obtain a short display time and automatic operation.

2. Turn FUNCTION switch to TEST.

3. Rotate MULTIPLIER switch to each marking for EPUT, starting with the 10^5 cps setting. This should give a reading of 10. As the switch is turned clockwise, other settings should read 100, 1,000, 10,000, 100,000 and 1,000,000 respectively.

Note that the DISPLAY TIME is infinite at the extreme clockwise position of the control. In this position, the instrument must be reset manually.

COUNT Operation

The unit counts the input to the X channel during the period the count switch isi in the ON position.

1. Connect input to X (COUNT) channel. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments" above.)

2. Place COUNT switch in off position.

3. Rotate FUNCTION switch to COUNT.

4. Depress manual RESET button.

5. Snap COUNT switch to ON to begin counting.

6. Snap COUNT switch to opposite position to stop counting.

7. Read count from lighted Decimal Counting Units (DCU's).

8. Depress RESET button to remove count and reset instrument.

EPUT (Events-Per-Unit-Time) Operation

The unit counts the input to the X channel between start and stop signals separated by a precise time interval known as the time base. This setting may be used to measure the frequency of a signal or the number of events occuring within a selected time interval.

1. Connect input to X (EPUT) channel. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments " above.)

2. Rotate the FUNCTION switch to EPUT.

3. Rotate the MULTIPLIER switch the desired time base frequency on the EPUT scale. The time interval during which the units count is equal to 1 divided by the time base frequency.

4. Adjust the DISPLAY TIME control to the position at which the count on the lighted DCU's may be read conveniently.

5. To obtain a reading in events per second, multiply the reading on the lighted DCU's by the factor on the EPUT scale to which the MULTIPLIER switch is set.

Extension of EPUT Operation Time Interval

The time interval during which events are counted may be extended to any multiple of the one or ten second time base periods. Consider the total measuring interval desired as N time base periods. Proceed as follows:

1 & 2. Follow steps 1 & 2 under "EPUT Operation".

3. Snap COUNT switch to ON position.

4. Rotate DISPLAY TIME control to extreme clockwise position.

5. Rotate MULTIPLIER switch to the 1 or 10^{-1} position on the EPUT scale.

6. Hold a stopwatch in one hand. Place the other hand on the FUNCTION switch and the RESET button. Depress the RESET button. Within one second the instrument will begin a normal EPUT counting period.

7. Before the end of this period (one or ten seconds, as the

case may be) turn the FUNCTION switch to the COUNT position and begin timing N minus 1 counting periods with a stopwatch.

8. At the end of N minus 1 periods, turn the FUNCTION switch back to EPUT.

9. When the last counting period has expired, read the count on the DCU's.

GATE Operation

The unit counts the signal at the X INPUT during the interval between a voltage excursion through a selected level at the Y (START) INPUT and a voltage excursion through an independently chosen level at the STOP INPUT.

1. Connect input to be counted to the X channel, the start signal to the Y (START) INPUT and the stop signal to the STOP INPUT (See "Input Adjustment" above.)

2. Rotate FUNCTION switch to GATE.

3. Adjust the DISPLAY TIME control to the position at which the count on the lighted DCU's may be read conveniently.

4. Read the count on the DCU's.

$\frac{X}{Y}$ Operation

The unit counts the signal at the X INPUT between consecutive voltage excursions through a selected level at the Y INPUT. This setting may be used to measure the ratio of two frequencies or to count the number of events occurring while the Y INPUT is above or below a given voltage level.

1. Connect the higher frequency to the X INPUT jack and the lower frequency to the Y INPUT jack. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments" above.)

2. Rotate the FUNCTION switch to X/Y. In this position the POLARITY switch nearest the Y INPUT determines the polarity of the voltage excursion which begins count of the X input. The other polarity switch sets the polarity of that which ends the counting period.

3. Therefore,
   a) When measuring the ratio of two frequencies set both polarity switches to "+" or both to "-".

(b) When counting the X input during the period the Y input voltage remains above a certain level, set the POLARITY switch nearest the Y INPUT to "+" and the other to "-".

(c) When counting the X input during the period the Y input voltage remains below a certain level, set the POLARITY switch nearest the Y INPUT to "-" and the other to "+".

4. Adjust the DISPLAY TIME control to the position at which the count on the lighted DCU's may be read conveniently.

5. Take a reading. When measuring a frequency ratio the DCU's indicate the ratio of the X input frequency to the Y input frequency.

$\frac{10X}{Y}$ Operation

The unit counts the signal at the X INPUT between a voltage excursion through a selected level at the Y INPUT and the tenth following excursion. This setting will measure a frequency ratio more accurately than the X/Y operation.

1. Connect the higher frequency to the X INPUT JACK and the lower frequency to the Y INPUT jack. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments" above.)

2. Rotate the FUNCTION switch to 10X/Y. The POLARITY switches may be in any position

3. Adjust the DISPLAY TIME control to the position at which the count of the lighted DCU's may be read conveniently

4. Divide the reading by 10 to obtain the ratio of the X INPUT frequency to the Y INPUT frequency

TIM (Time Interval Meter) Operation

The unit measures the time between a voltage excursion through a selected level at the Y (START) INPUT and a voltage excursion through an independently chosen level at the STOP INPUT.

1. Connect the start signal to the Y INPUT and the stop signal to the STOP INPUT. (See "Input Adjustments" above.)

2. Rotate the FUNCTION switch to TIM

3. Rotate the MULTIPLIER switch to the desired unit of time measurement on the TIM scale. For example, at the 10^{-4} position the time measurement appears in ten-thousandths of a second. The smaller the time unit chosen, the more accurate the reading.

4. Adjust the DISPLAY TIME control to the position at which the count on the lighted DCU's may be read conveniently.

5. To obtain a reading in seconds, multiply the count on the DCU's by the factor on the TIM scale to which the MULTIPLIER switch is set.

PERIOD Operation

The unit measures the time interval between consecutive voltage excursions through a selected level at the Y INPUT. This setting may be used to measure the period of a wave or the width of a pulse.

1. Connect the wave or pulse source to the Y (PERIOD) INPUT. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments" above.)

2. Rotate the FUNCTION switch to PERIOD. At this position the POLARITY switch nearest the Y INPUT selects the polarity of the voltage excursion which begins the timing period. The other POLARITY switch selects the polarity of that which ends the timing period.

3. Therefore,
   a) When measuring the period of a wave, set both POLARITY switches to "+" or both to "-".

   b) When measuring the width of a positive pulse, set the POLARITY switch nearest the Y INPUT to "+" and the other to "-"

   c) When measuring a negative pulse, set the POLARITY switch nearest the Y INPUT to "-" and the other to "+".

4. Follow steps 3, 4 & 5 under "TIM Operation".

PERIOD x10 Operation

The unit measures the time interval between a voltage excursion through a selected level at the Y INPUT and the tenth following excursion. This setting will measure the period of a wave more accurately than the PERIOD operation.

1. Connect the wave source to the Y (PERIOD) INPUT. (See "CONTROL and CONNECTOR FUNCTIONS, Input Adjustments" above.)

2. Rotate the FUNCTION switch to PERIOD x 10. The POLARITY switches may be in any position.

3, 4 & 5. Follow steps 3, 4 &5 under "TIM Operation".

6. Divide the reading by 10 to obtain the length of one period.

ACCURACY

Measurements are subject to three important sources of error:

1. The inherent counting limitation of the instrument.
2. Oscillator drift.
3. Noise on the attenuated signal to the Y or STOP channel.

1. Any measurement made by counting the number of events occuring during a precise interval (i. e. all measurements except COUNT) may vary plus or minus one count. This variation is caused by events which occur simultaneously with the opening or closing of the Signal Gate. The following equation edfines the possible error introduced

$$\text{(1) Maximum percent error} = \frac{1}{\text{Count Indication}} \times 100.$$

Therefore, measurements set up to yield the highest count indication will be most accurate. High frequencies yield the highest count indication when measured using the EPUT function and a long gate time interval. Low frequencies yield the highest count indication when measured with the PERIOD or PERIOD x10 function and a short unit of time measurement. The accuracy achieved using alternative functions at various frequencies is graphically illustrated in Figure 3. Note that the curves for PERIOD x10 and

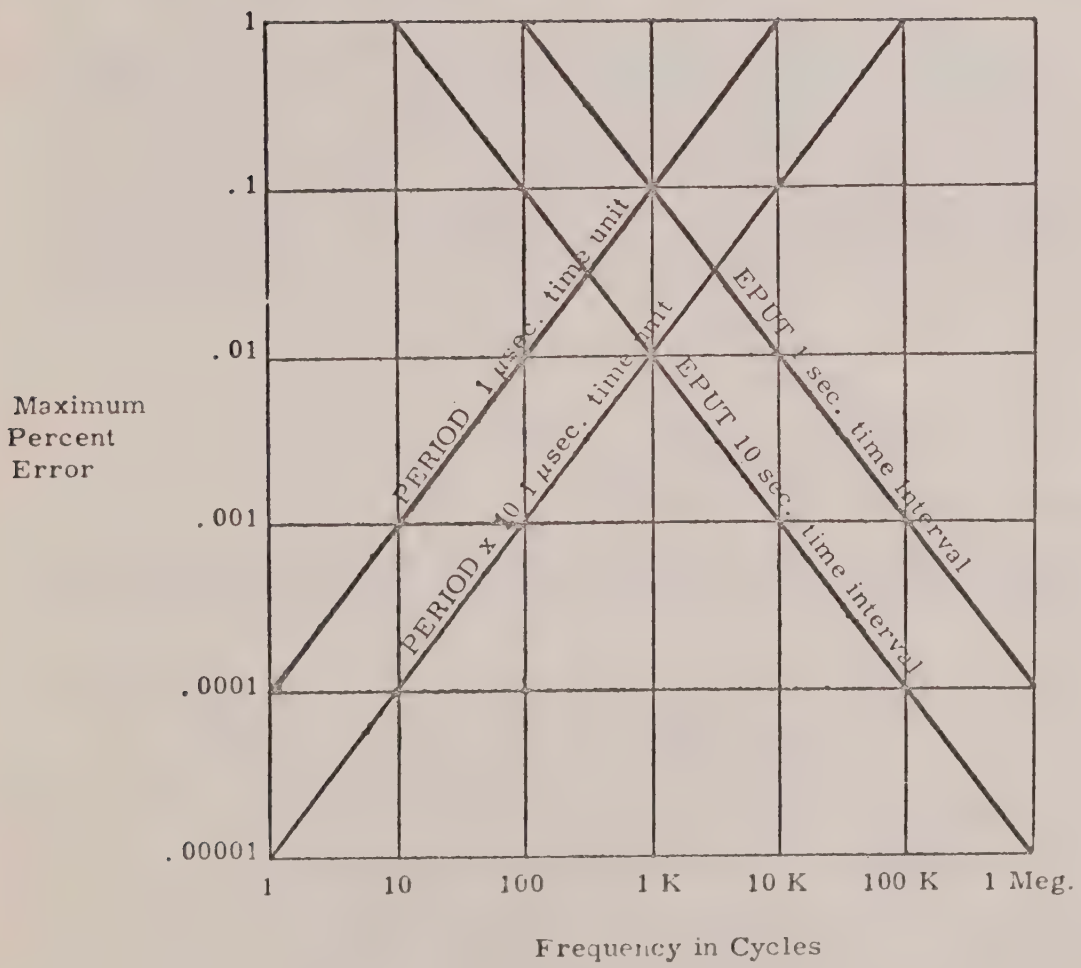


FIGURE 3. ERROR DUE TO ± 1 COUNT LIMITATION

EPUT functions cross at 1 KC. Using either the EPUT function and the 10 sec. time interval or the PERIOD x 10 function and the 1 μsec. unit time, the maximum possible error at this frequency is .01%. Other frequencies may be measured with greater accuracy.

2. All measurements requiring a signal from the time base (i.e. EPUT, PERIOD PERIOD x10 & TIM) are subject to an additional error introduced by variations in the oscillator frequency. Since the oscillator is crystal controlled, its drift is limited to 1 part in 1,000,000. The maximum percent error from this cause is .0001%.

3. Measurements using an external signal to trigger start and stop pulses (PERIOD PERIOD x10, TIM, GATE, X/Y & 10X/Y may be subject to further error caused by extraneous noise on the attenuated input signal. The total signal may be considered as an ideal signal intended to trigger the input channel plus a noise signal. The noise voltages added or subtracted from the ideal signal may trigger a pulse before or after the instant at which counting should begin or end. (See Figure 4). The maximum error in the time of triggering will be proportional to the noise amplitude and inversely proportional to the slope of the ideal signal at the trigger level. Expressed mathematically,

$$t\ (\text{secs}) = \frac{V_n\ (\text{volts})}{S\ (\text{volts/ sec})}$$

Where t = Max. error in trigger time
V_n = peak-to-peak noise
S = slope of ideal signal at trigger level.

For PERIOD and PERIOD x 10 measurements the error may be expressed as a percentage by dividing the error in trigger time by the total measurement and multiplying by 100.

For PERIOD
General case:

(2) Max. percent error $= \frac{t\ (\text{secs})}{T\ (\text{secs})} \times 100$

where T = one period of input signal

In the case of a sine wave triggering at its zero crossover value:

(3) Max. percent error $= \frac{V_n\ (\text{volts})}{V_s\ (\text{volts}) \times \pi} \times 100$

Where V_n = peak-to-peak noise
V_s = peak-to-peak signal

The maximum percent error of PEHOD x 10 measurements is one-tenth the value given in equations (2) or (3).

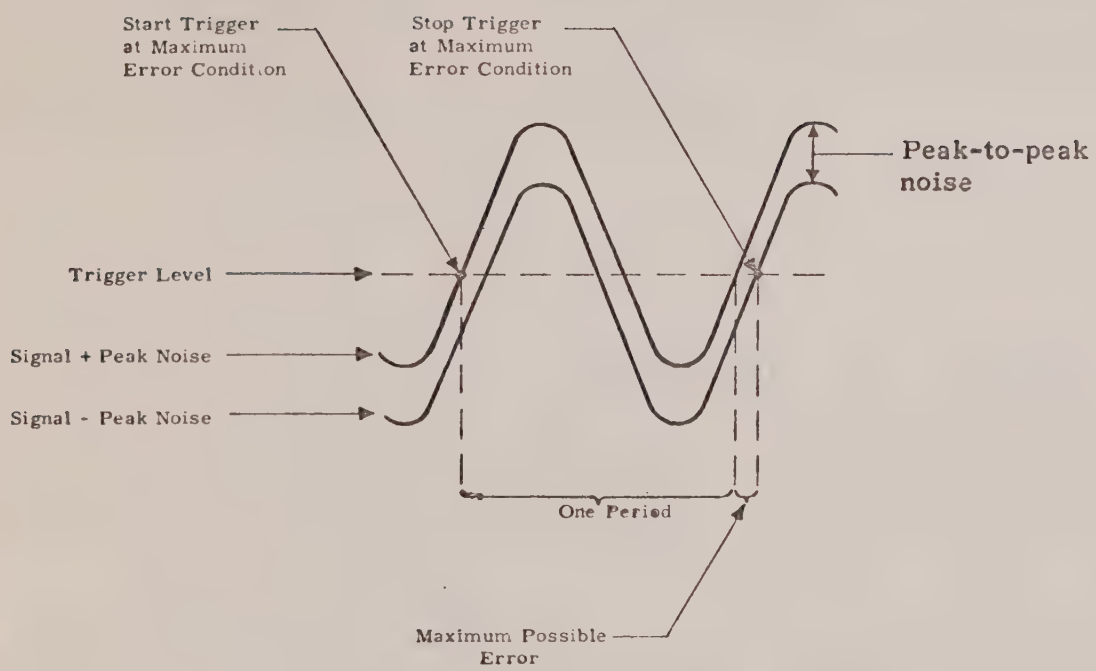


Figure 4 Effect of Noise on Period Measurements

The total error due to the three causes mentioned above is equal to the sum of the separate errors.

$$\text{Total Max. percent error} = \frac{100}{\text{Count indication}} + .0001 + \text{Percent error due to signal noise}$$

If any function except COUNT

If EPUT PERIOD PERIOD x10 or TIM

If PERIOD PERIOD x10 TIM GATE $\frac{X}{Y}$ or $\frac{10X}{Y}$

PRECISION PHASE MEASUREMENTS

The Model 5510 Universal Counter and Timer may also be used to make precise phase difference measurements at audio frequencies. The 10-megohm impedance of its input circuits allows direct connections to most phase-shifting circuits without causing excessive loading. The following example will illustrate such use of the instrument

PROBLEM: Measure the phase difference at 30 cps between the input voltage and the current flowing through a capacitor of 0 1 μf and a resistance 100, 000 ohms connected in series

The voltage developed across the resistor is in phase with the current, so if we compare the phase of this voltage to that of the input voltage we will have the solution. Set up the equipment as shown in Figure A.

Set the FUNCTION switch to TIM, the MULTIPLIER to 10^{-6}, and turn the DISPLAY TIME Control to the extreme clockwise position. Set both POLARITY switches at "+" and turn both the START and STOP trigger level controls fully clockwise. Set the DC point on both the START and STOP attenuators to the lowest attenuation factor which is not less than 1/2 the peak AC output from the oscillator, measured in volts

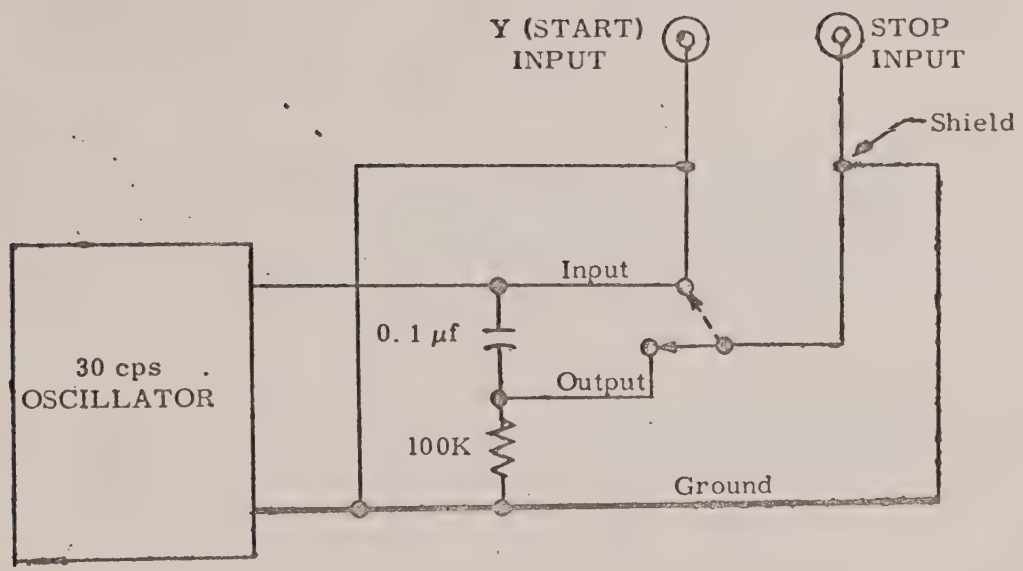


FIGURE A CONNECTIONS TO PHASE-SHIFTING NETWORK

With both the START and STOP input cords disconnected at the Model 5510 INPUT jacks, manually reset the instrument. Slowly turn the START TRIGGER LEVEL control counterclockwise, stopping at the position that starts the instrument counting. Then slowly turn the STOP TRIGGER LEVEL control counterclockwise, stopping at the position that stops the instrument counting. Both input cha nels are thus adjusted to trigger near zero voltage, which is the "zero crossover" voltage of a sine wave input. The "zero crossover" point is the reference chosen for these measurements because the input wave has its maximum slope at this point. Plus, for a given percentage of amplitude variation of the triggering voltage, the error in timing is as small as possible. This procedure assures maximum accuracy of phase measurement in the presence of noise, as explained on page 15 under paragraph 3 of the section discussing measurement accuracies.

Next, connect the START INPUT channel to the input of the phase-shifting network as shown in Figure A. Turn the FUNCTION switch to PERIOD and turn the DISPLAY TIME control counterclockwise until the display time is such that the DCU's can be read conveniently. The instrument is now reading the "period" of the input wave, or the time required for a complete cycle or 360^{o} of this wave. Note this value as N_1 for future

reference. For the 30-cycle input assumed for the problem, N_1 should be approximately 33, 333 microseconds. If the frequency of the 30-cycle oscillator is accurately known, the START TRIGGER LEVEL control should be trimmed slightly to obtain the proper reading of N_1. This adjustment provides maximum accuracy by triggering the START INPUT channel as near to the "zero crossover" point as possible.

Now return the FUNCTION switch to the TIM position and connect both the START and STOP INPUT channels to the input of the phase-shifting network with the switch in the "dotted-line" position shown in Figure A. Trim the TRIGGER LEVEL control of the STOP channel until a reading of N_1 appears. (Both POLARITY switches should be in the "+" position). Both the START and STOP channels are now triggering at the same voltage point on the input wave, near the "zero crossover" point.

Next, move the STOP channel input to the output of the phase shifting network with the switch in the "solid-line" position shown in Figure A. Note the reading on the DCU's as N_2. N_2 is the time delay between the "zero crossover" of the input (or reference) wave of the network and the "zero crossover" of the output (or shifted) wave of the network. This delay may be expressed in degrees of phase lag from the expression

$$\phi = \frac{360\ N_2}{N_1}$$

where ϕ is the phase lag in degrees. For the simple network of 0.1 μf and 100,000 ohms assumed for this problem, ϕ at 30 cps is approximately 332 degrees, and N_2 should thus have been approximately 30,740 microseconds. In the event that the signal voltage amplitude at the output of the phase-shifting network is different from that at the input (which is the case with many networks), the above procedure for adjusting the trigger levels to the "zero crossover" point will minimize the error produced by this difference. Ideally, the "zero crossover" remains at the same point in timing on a wave regardless of amplitude variations of the wave.

Direct-Reading Phase Angle Meter

The Model 5510 can be used in conjunction with an external high frequency oscillator to provide measurements directly in degrees (or any other unit) using a technique similar to that described above.

Instead of using the PERIOD function to measure N_1, the function switch should be placed in the X/Y position and the frequency of an external oscillator connected to the X INPUT jack adjusted to give a reference indication (N_1) for a full wave of the phase network input frequency. A

convenient expression for determining the X INPUT frequency when a reading is desired directly in degrees is

$$f = \frac{360F}{r}$$

where f is the X INPUT frequency, F is the phase network input frequency and r is the desired resolution (or phase shift corresponding to one digit on the right-hand DCU) in degrees. In the example cited, the proper X frequency for a resolution of 0.1 degrees is

$$f = \frac{360 \times 30}{0.1} = 108,\ 000 \text{ cps or } 108\text{KC}.$$

The reading thus observed for N_1 should be 3600.

With both the START and STOP channel inputs connected to the input of the phase shift network (Figure A, switch in "dotted-line" position), turn the function switch to GATE and adjust the STOP TRIGGER lever to again obtain a reading of N_1.

Now move the STOP INPUT channel to the output of the phase-shifting network (Figure A, switch in "solid-line" position) and read the phase lag directly on the DCU's. In the example cited the reading is in tenths of a degree.

It should be remembered that the frequency used at the X INPUT circuit must not exceed one megacycle. Phase measurements made with a resolution of one degree, for example, must be limited to frequencies of 2778 cps or less on the phase shifting network.

Accuracies of Phase Measurements

As was pointed out in the section covering general digital measuring accuracies, several factors affect the accuracy of measurement. There is, of course the possible error of ±1 count in the right-hand DCU. In the example cited, using the direct-indicating procedure described immediately above, this means an error of ±0.1 degree from this source.

It is also necessary to insure that the short-term frequency stability of the oscillators used to drive the phase shifting network and to provide the X input frequency is within the requirements of the measurement. For example, if it is desired to make measurements with an accuracy of 0.1 degree it is necessary that the short-term stability of these oscillators be at least 1 part in 3600.

The loading caused by connecting the input impedances of the START and STOP channels to the phase shifting network is another possible source of error. In the example cited, the 10-megohm input impedance of the STOP channel connected across the 100,000 ohm resistor changes the effective value of this resistor by about 1 percent. This is equivalent to shifting the phase by approximately two degrees. Smaller errors would, of course, be observed using phase-shifting networks of lower impedance.

The error caused by harmonics, hum, and other extraneous noise on the START and STOP input circuits may be more conveniently expressed, when applied to phase measurements, by the expression

$$\frac{E_n \text{ (volts)}}{E_s \text{ (volts)}} = \frac{k\,\pi}{360}$$

where E_n is the peak noise on the START and STOP channels (harmonics, hum etc., including the equivalent noise input voltage of the channels), E_s is the peak START or STOP signal voltage, and k is the required accuracy in degrees. This, then, indicates that in order to make phase measurements accurate to 0.1 degree the ratio of E_n to E_s must be at least 1 to 1150, or a signal to noise ratio of about -62 decibels must be achieved. The above expression assumes that both the START and STOP INPUT channels TRIGGER LEVELS have been carefully adjusted to the "zero crossover" point of the input signals so that no error is introduced from a difference in amplitude of the two signals.

The total error in phase measurements is the sum of the individual errors described above.

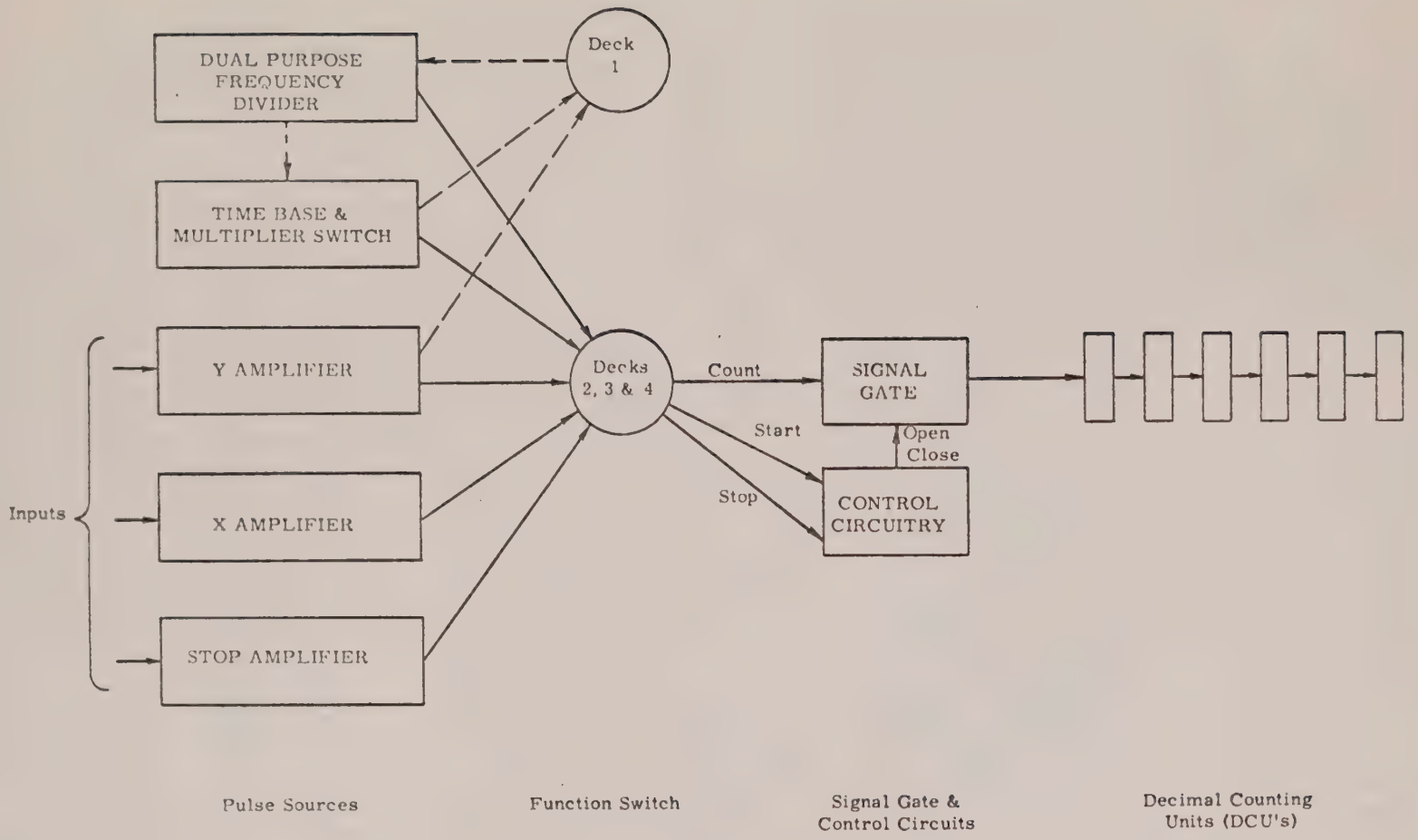


FIGURE 5 SIGNAL PATHS BETWEEN MAJOR COMPONENTS OF MODEL 5510

3 Theory

OVER-ALL DESIGN

The Model 5510 consists of an accurate time base, three input amplifier circuits, an electronic gate and a series of cascaded Decimal Counting Units. The functional diagrams of Figures 6 & 7 show how the components are connected to make various measurements. All functions except COUNT require three signals: a start pulse to open the signal gate, pulses to be counted and a stop pulse to close the signal gate. The DCU's count and indicate the number of pulses occuring between the start and stop pulses. Which function is performed is determined by which pulse source is selected to provide each of the three signals. Pulse sources used are the three input amplifiers and the time base. For certain operations the output of one of these sources is fed through the Dual Purpose Frequency Divider before being used. (See Figure 5.)

Pulses to be counted are drawn from either the X input amplifier or the time base. When X amplifier pulses are counted the DCU's indicate number of events, frequency or frequency ratio. When time base pulses are counted the DCU's indicate a time interval or period. In EPUT operation pulses from the X amplifier are counted over a period determined by start and stop pulses from the time base. For TIM operation pulses of known frequency from the time base are counted over the unknown interval between a pulse from the Y (START) amplifier and a pulse from the STOP amplifier. Since the time base selected is a power of ten times the 1 μsecond oscillator period, the time measurement appears directly in decimal fractions of a second. The selection of pulse sources for other functions may be determined from the functional diagrams of Figures 6 & 7.

SIGNAL GATE AND CONTROL CIRCUITS

Decks 2, 3 & 4 of the FUNCTION switch select respectively the pulses to be counted, the start pulse and the stop pulse. Pulses to be counted are led to the signal gate (V112), the start pulse to the Start Gate (V114) and the stop pulse to the Stop Gate (V115). When the unit is operating the following sequence occurs. (Refer to the functional diagram, Figure 8.)

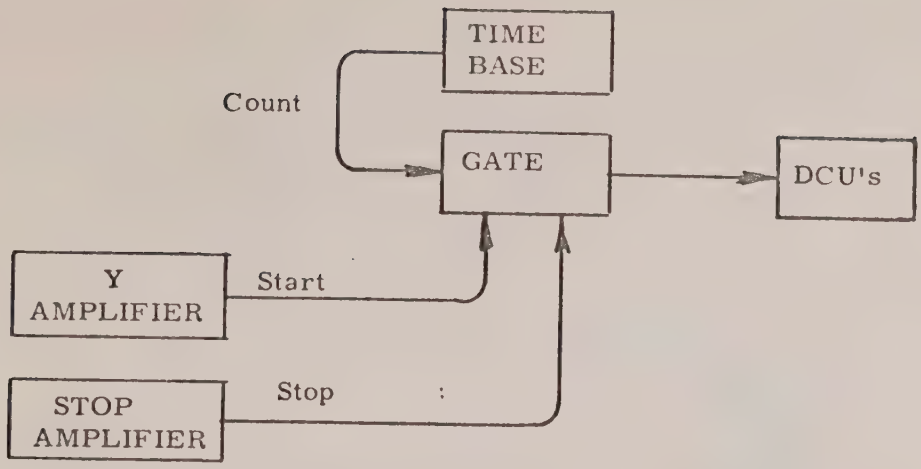
1. A start pulse

    a. Opens the Signal Gate through the Gate Control Binary.

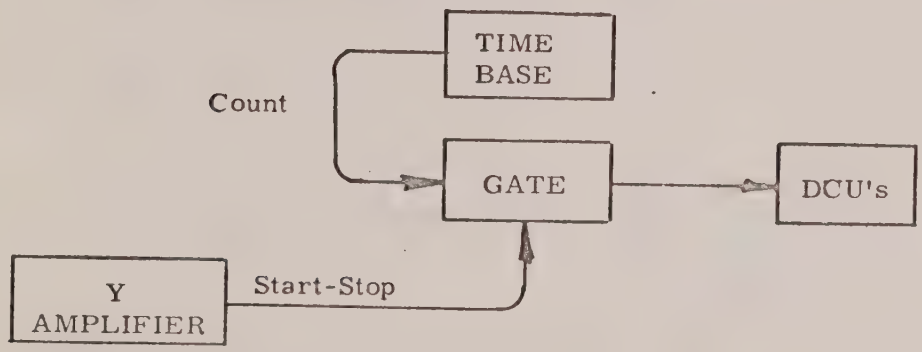
    b. Closes the Start Gate through the Latching Binary.

    c. Opens the Stop Gate, after a 3 μsecond delay, through the Gate Control Binary.

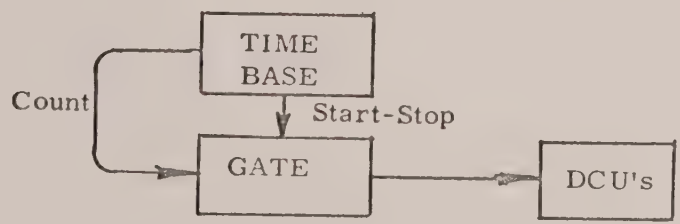
TIM



PERIOD



TEST



NOTE. For PERIOD x 10 and $\frac{10X}{Y}$ operation the Y Amplifier pulses are fed through the Dual Purpose Frequency Divider which produces an output pulse at every tenth input pulse.

FIGURE 6. ARRANGEMENT OF MAJOR COMPONENTS FOR VARIOUS MEASUREMENTS

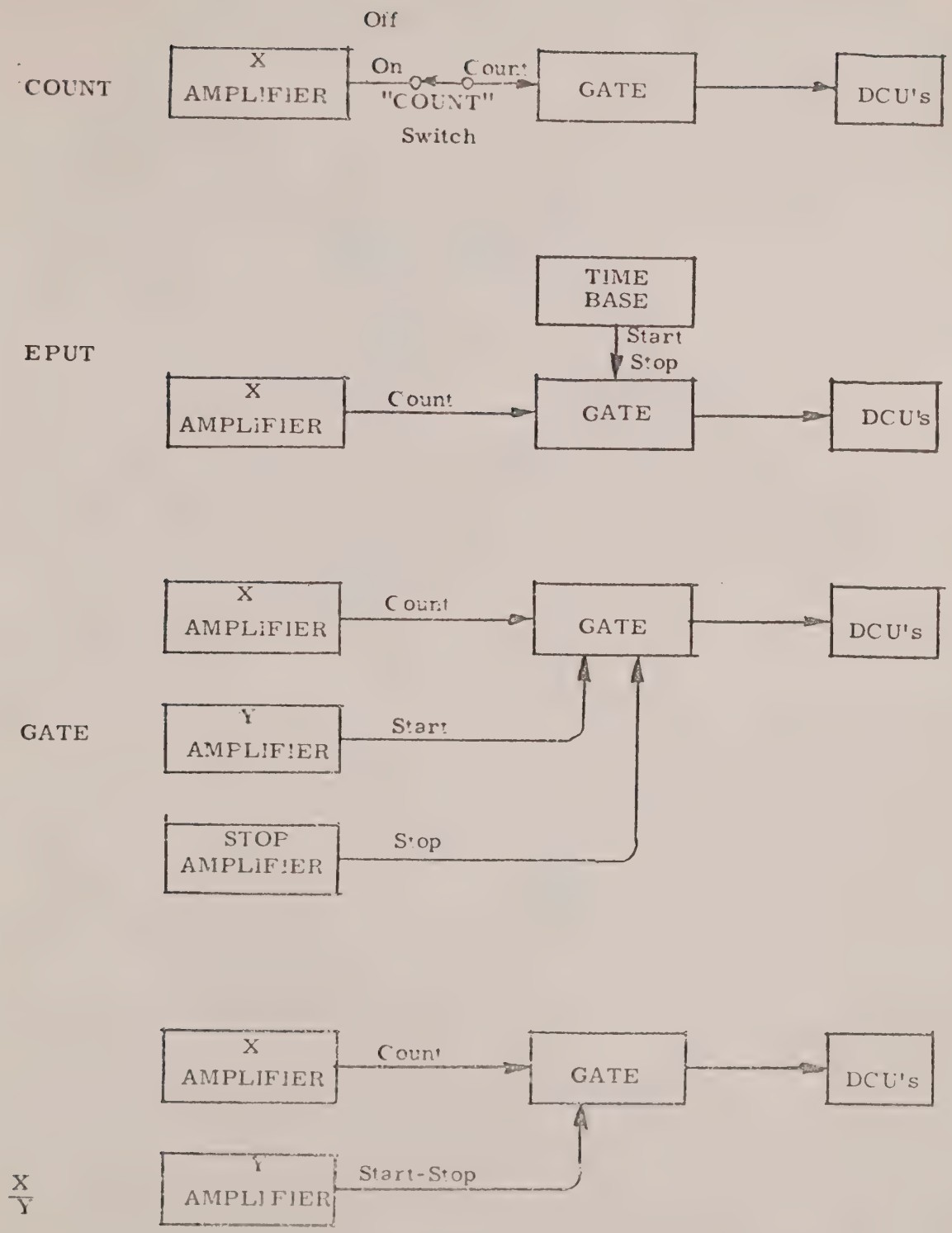
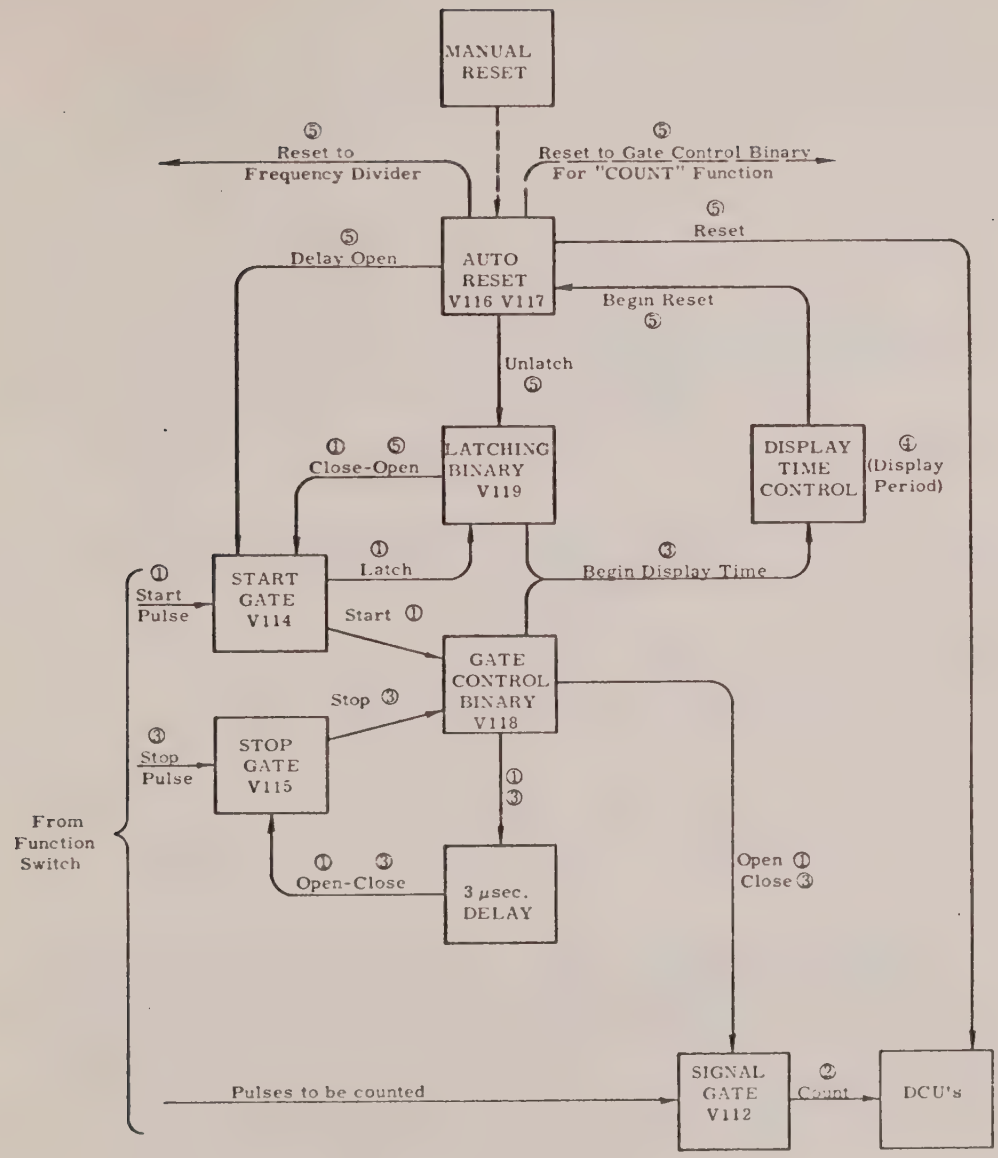


FIGURE 7. ARRANGEMENT OF MAJOR COMPONENTS FOR VARIOUS MEASUREMENTS



NOTE: Circled numbers indicate sequence of operations.

FIGURE 8 FUNCTIONAL DIAGRAM OF SIGNAL GATE & CONTROL CIRCUITS

2. Pulses to be counted are passed through the Signal Gate and counted on the DCU's.

3. A stop pulse

a. Closes the Signal Gate through the Gate Control Binary.

b. Closes the Stop Gate through the Gate Control Binary.

c. Initiates a slow voltage change in the Auto Reset circuit through the combined action of the Gate Control Binary and the Latching Binary.

4. The DCU's are now displaying the count. Start, stop and signal gates are all closed.

5. When the voltage in the Auto Reset circuit reaches a certain level the circuit generates a pulse which

a. Resets all the DCU's to zero.

b. Opens Start Gate after a 1000 μsecond delay. (The pulse flips the Latching Binary to a position which permits the Signal Gate to open after delay.)

c. Resets the Dual Purpose Frequency Divider to 9.

6. The circuitry is now prepared to repeat the above sequence 1 through 5.

The Signal Gate and Control Circuitry uses three ; 6AS6 pentodes as gate tubes, V114, V115 and V112. These pentodes will amplify a pulse on the signal gird when the suppressor grid is near ground. When the suppressor grid is sufficiently negative they will produce no output and may be considered closed. The voltage on the suppressor grid is produced in each case by one plate of a controlling binary. As the binary is switched from one to the other of its two stable states the associated gate tube is opened and closed.

The Stop Gate (V115) and Signal Gate (V112) are controlled by the Gate Control Binary (V118). The opening of the Stop Gate is delayed 3 μseconnds by the integrating action of R224 and C163. The Start Gate (V114) is controlled by the Latching Binary (V119. The opening of the Start Gate tube is delayed because its cathode is charged positive across C208 by the reset pulse current through the diode V120A . In about 1000 μseconds C208 discharges through R260 to

ground potential where it is clamped by the current through V120A. The Start Gate tube is then free to conduct.

Each of the two binaries flips from one to the other of its two stable states when it receives a negative pulse at its non-conducting plate. The Gate Control Binary (V118) receives pulses from the Start Gate (V114) at its right plate and pulses from the Stop Gate (V115) at its left plate. The Latching Binary (V119) receives a pulse from the Start Gate at its right plate. A positive pulse at the grid of its non-conducting side will also switch a binary to its other state. A positive reset pulse from T101 reaches the left grids of both V118 and V119.

The display period is initiated when the grid of V116A drops to a certain negative potential. Through the voltage dividing action of R249 and R247 this grid is held at a potential midway between the left plate of the Gate Control Binary (V118) and the right plate of the Start Gate Latch (V119). The grid of V116 goes sufficiently negative only when both these plates are in their negative stable state. This occurs only once in a counting cycle, just after the stop pulse.

When the grid of V116 swings negative the plate goes positive, slowly charging C164 through the DISPLAY TIME potentiometer R230. This charge is applied to the plate of the thyratron (V117) and, through the cathode follower V116B, to the thyratron grid. After a period determined by the setting of the DISPLAY TIME potentiometer the thyratron grid reaches ground and the tube fires discharging C164 into the reset circuitry. The reset pulse is led through R258 and C212 to the DCU's and through R259 and T101 to the Dual Purpose Frequency Divider, the grid of V118A (one side of the Gate Control Binary) and the grid of V119A (one side of the Gate Control Latch Binary).

"COUNT" OPERATION CIRCUITRY

The COUNT operation differs considerably from other functions. Start pulses from the 10^{-4} sec. time base divider open the Signal Gate. While the Signal Gate remains open, counting is started and stopped by simply connecting and disconnecting the source of pulses to be counted. No stop pulse is used.

Before beginning a COUNT measurement, the operator presses the manual RESET button (S110) to clear the DCU's and to insure that the Start Gate will be open to pass the start pulse. S110 places a positive voltage on the thyratron plate and on the thyratron gird

through the cathode follower V116B. The thyratron fires immediately sending a reset pulse to the DCU's and to a grid of the Latching Binary This pulse flips the Latching Binary to a state which holds the Signal Gate open

Start pulses travel from the divider through the Start Gate to the Gate Control Binary, which is flipped to the state which holds the Signal Gate open Pulses to be counted travel from the X Amplifier through the COUNT switch (S108) to Deck 2 of the FUNCTION switch and from there to the Signal Gate. Counting is started by placing the COUNT switch in the ON position and stopped by flipping it to the opposite position.

Since no stop pulse arrives to initiate the display period and reset action, the DCU's display the count indefinitely. The unit is reset by depressing the manual RESET button.

TIME BASE

The time base provides

1. A known frequency which is counted between start and stop pulses to make time measurements

2. Start and stop pulses separated by a known time interval over which events are counted to make EPUT measurements

The circuitry includes a stable crystal controlled oscillator (V121), a pulse shaping circuit (V122) and six frequency dividing stages consisting of two blocking oscillators (V123 A & B), and four one-shot multivibrators (V124 to V127). An additional dividing stage, the Dual Purpose Frequency Divider, is available to provide a 10 second period when it is not being used to divide the output of the Y Amplifier. The shaper stage transforms the sinusoidal output of the oscillator into appropriate pulses. Each of the dividers divides the preceding frequency by ten. Decade frequencies from the shaper and the various dividers are selected by the MULTIPLIER switch, fed through the inverter V110A and applied to the FUNCTION switch, where thay are available for start, stop or pulses to be counted.

The V121 oscillator circuit consists of a two-stage amplifier with a feedback loop tuned by a series-resonant crystal network. The network passes a 1MC signal in phase, but introduces a phase shift which prevents regeneration at all other frequencies. Fine

oscillator frequency adjustment is made by varying C181 by means of the GRID TUNE control. The parallel-resonant network at the output plate is adjusted by varying C183 through the PLATE TUNE control.

The 1 MC sine wave output of the oscillator (V121) is applied to the grid of V122A, the input of the pulse shaping circuit. V122 amplifies over a narrow voltage range but has negligible gain beyond this range. The oscillator signal drives the tube considerably beyond this range, producing an square current wave at both plates. A resistor-inductor-rectifier network modifies the current wave to produce negative voltage pulses at R269. A resistor-inductor network produces positive voltage pulses at R271. The negative pulses are led to the 1 MC position on the MULTIPLIER switch. The positive pulses are led to the grid of the first frequency divider. A positive 1 MC signal is also taken from the cathode of V122 to be counted during the TEST function.

The first frequency divider (V123A) is a free running blocking oscillator. When its grid rises above cutoff the tube begins to draw current through T102 whose secondary winding simultaneously reinforces the positive charge on the grid. This regenerative action produces a sharp rise in tube current and a correspondingly sharp dip in the plate voltage. Current drawn while the grid is positive charges C187 negative. At the peak of the output pulse this charge begins to drive the grid negative. The resulting drop in tube current, reflected again through T102, forces the grid rapidly below cutoff. The output pulse completed, the grid and C187 begin to accumulate a positive charge through R274 and R275. While the grid voltage curve is rising comparitively slowly toward cutoff, positive output pulses from the shaper are being superimposed upon it through C185. (See Figure 9). Since these pulses are higher than the grid voltage rise between pulses, the grid voltage will intersect the cutoff value only at one of the 1 MC shaper pulses. The rate at which the grid voltage curve rises toward cutoff and, consequently, which shaper pulse will drive it above cutoff, depend upon the values of C186, R274 and R275. R275 is adjusted so that every tenth pulse from the shaper will produce an output pulse from the divider. Negative 100 KC pulses from the plate are led to the MULTIPLIER switch. Positive output pulses from the cathode go to the grid of the second frequency divider V123B.

V123B is another blocking oscillator which divides its input in the same way as V123A. A negative 10 KC output pulse is led to the

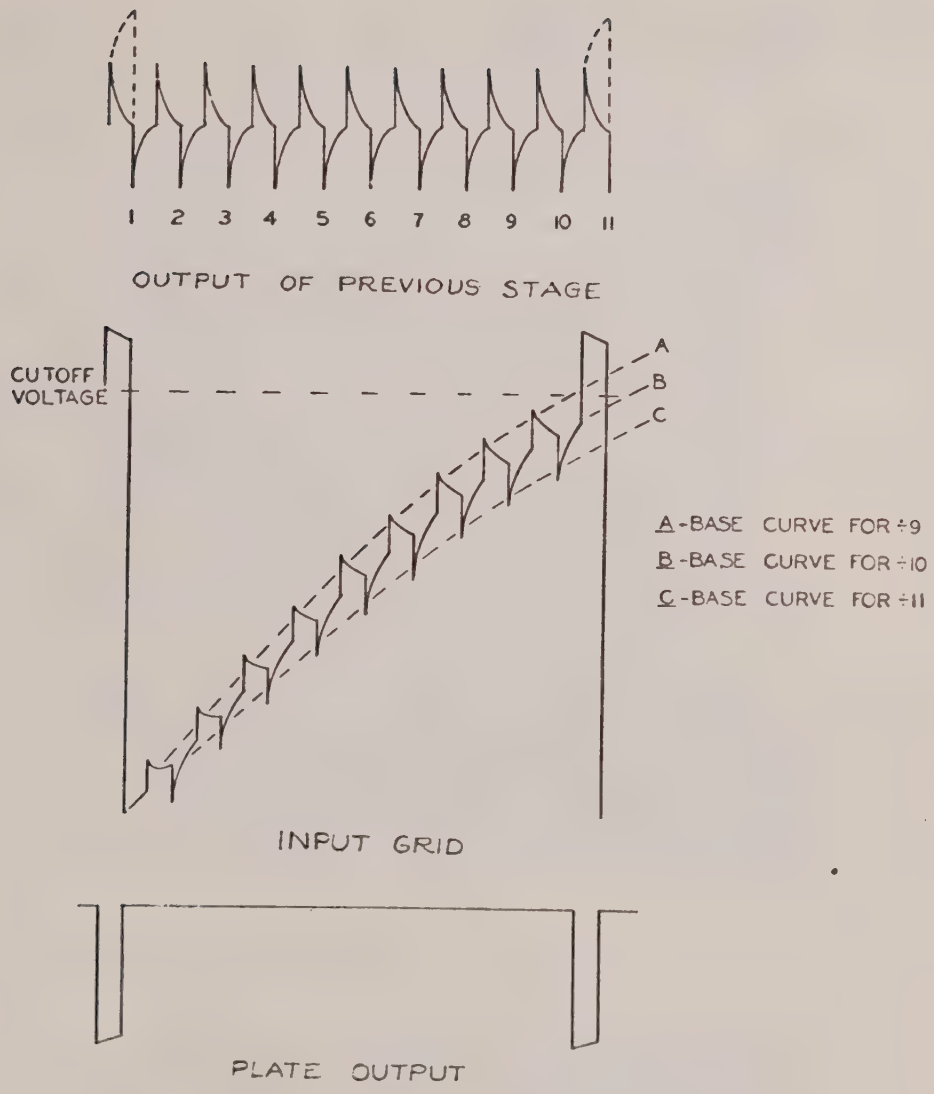


Figure 9 Divider Stage Waveforms

MULTIPLIER switch from the plate load resistance and a signal for the following frequency divider is drawn from the plate side of T103. This signal is a negative transient followed by a positive transient.

The next frequency divider (V124) is a one shot multivibrator circuit. With no input the circuit is in a stable state. V124A is cut off and V124B is conducting because its grid is tied to B+. When a negative transient from the previous divider reaches this grid through C193, an amplified positive signal appears at the plate of V124B. This voltage rise is conducted to the grid of V124A through C192 and R288. V124A conducts, producing a voltage drop at its plate which reinforces the negative transient at the grid of V124B through C193. This regenerative action produces a quasi-stable state in which V124B is cut off and V124A conducting. In this state the voltage on the grid of V124B is rising as C193 is charged through R294 and R295. At the same time the positive transients from the previous divider are superimposed on this rising curve through C193. (See Figure 9). When one of these transients brings the grid above cutoff V124B conducts and a reverse regenerative action returns the circuit to its original stable stage. Which of the successive positive transients will rise above cutoff is determined by the slope of the rising grid voltage curve. The slope is adjusted by varying R294 so that the tenth pulse reaches cutoff.

In the interval between the positive transient which turns on V124B and the succeeding negative transient which cuts off the tube, its plate is negative. The resultant rectangular negative pulse takes two paths: one to the MULTIPLIER switch and another through an R-C differentiating network to produce negative and positive transients to feed the next frequency divider. The remaining dividers, V125, V126 and V127, are one-shot multivibrator circuits which operate exactly as V124.

DUAL PURPOSE FREQUENCY DIVIDER

The DCU AY107 is used either to extend 1 second time base to 10 seconds or to divide the Y Amplifier output frequency by 10. The first deck of the FUNCTION switch selects the signal to be divided and feeds it through the inverter amplifier V111A to the divider.

The negative pulse from the 1 second position of the MULTIPLIER switch is led through the inverter amplifier V111B to the first deck of the FUNCTION switch. For all functions except PERIOD x 10 and $\frac{10X}{Y}$, this signal is switched to the divider. The divider output

is connected directly to the 10 second position of the MULTIPLIER switch.

The Y Amplifier output is connected directly to the first deck of the FUNCTION switch. For PERIOD x 10 and $\frac{10X}{Y}$ functions this signal is switched to the divider and through an output inverter (V110B) to start and stop decks (3 & 4) of the FUNCTION switch.

Unlike the counting DCU's which reset to zero the frequency divider resets to 9.

INPUT AMPLIFIERS

Each input amplifier is essentially a Schmitt Trigger circuit preceded by difference amplifier and followed, except in the case of the X Amplifier, by an inverter stage. The amplifiers are used to produce a narrow voltage pulse each time the input voltage passes a certain trigger level.

Since the Y and STOP Amplifiers are identical only the Y Amplifier will be described. The attenuated input signal is conducted to the grid of V104A. When the attenuator switch is at an AC position the input is blocked by C117 so that only the AC signal component reaches the grid. When the switch is at a DC position C117 is bypassed and the attenuated DC level appears at the grid. V104A and V104B make up a difference amplifier whose output is primarily determined by the voltage difference of its two grids. At any instant the voltage at the plate of V104B is proportional to the voltage on the grid of V104A minus the constant voltage on the grid of V104B. Hence the signal at the grid of V104A is reproduced amplified at the plate of V104B. The voltage on the grid of V104B merely adds or subtracts a constant value from the plate voltage, thereby raising or lowering the level of the amplified output signal. The TRIGGER LEVEL potentiometer may be adjusted to choose the fixed voltage on the grid of V104B and, consequently, the level of the output signal.

The signal from the plate of V104B is applied to the control grid of V105 which together with V106A, forms a Schmitt Trigger circuit. Such a circuit characteristically exhibits two stable states. The output tube (V106A) draws a steady current as long as the input to V105 remains below a certain triggering voltage. When the input exceeds this voltage the output tube is suddenly cut off. When the input voltage returns to a value slightly below the triggering voltage the output tube builds rapidly to its original steady current. The

sudden plate current variations in V106A are differentiated by L102 to produce a positive pulse when the circuit is triggered by a rising voltage and a negative pulse when triggered by a falling voltage.

Consider the input to the Schmitt Trigger circuit as an a-c triggering signal superimposed on a d-c level. The input voltage at the grid of V105 which will trigger the Schmitt Trigger circuit is fixed, but the d-c level of the triggering signal may be varied by adjusting the TRIGGER LEVEL control. As the d-c level is raised the circuit triggers at a lower instantaneous voltage of the a-c signal, and (since this signal corresponds to the voltage variations on the grid of V104A) the circuit triggers at a lower attenuated input voltage to the amplifier. As the d-c level of the triggering signal is lowered, a higher input voltage is necessary to trigger the circuit.

The positive and negative output pulses from the Schmitt Trigger are fed to the grid of an inverter V106B. Pulses of the same sign are drawn from the cathode of that tube and pulses of opposite sign from the plate. Further circuitry is designed to receive only positive pulses. If a triggering point has been selected on the falling part of an input wave, the negative pulse produced by the Schmitt Trigger must be inverted before being used. The POLARITY switches S104 and S105 are provided to select pulses of suitable polarity. The Schmitt Trigger pulse is inverted when the associated switch is in the "-" position.

The X Amplifier employs a two stage difference amplifier (V101 and V102) and a Schmitt Trigger (V193) which produces narrower pulses than the trigger circuit of the Y Amplifier. The output pulse may not be inverted, so the X Amplifier is always triggered by a rising voltage. In other respects this amplifier operates in the same way as the Y and STOP Amplifiers.

POWER SUPPLY

The power supply provides plus and minus 150 volt unregulated power to the Decade Counting Units and plus 100, minus 60 and minus 100 volt regulated power to the rest of the circuitry. The negative 100 volt regulated supply is drawn from the cathode of the VR tube V403. The current drawn is too little to upset the action of the VR tube which maintains a constant potential of 100 volts across its terminals.

Regulation of the 100 volt positive supply is accomplished by degenerative voltage feedback through V401 to V402A, which is in series with the supply current. V401 picks up a fractional sample of the supply voltage at its control grid, compares this with a

fixed reference voltage at its cathode and supplies a signal to the grid of V402A which holds the supply voltage near a fixed value. The VR tube V403 provides a reference potential 100 volts positive of the VR cathode. The control grid of V401 gets a fraction of the supply voltage from the resistors R405, R406 and R407, which are connected in series from the VR cathode to V402A where the regulated output appears. When the output voltage rises, the control grid V401 moves positive and its plate drives the grid of V402A negative, which, in turn, reduces the rise in output voltage. Compensation occurs in the opposite direction when the output voltage falls. The level of the output voltage may be varied by adjusting the potentiometer R407 through the control labeled "B+ VOLTS ADJ."

Regulation of the negative 60 volts supply is accomplished in the same way except that the voltage comparison tube is a difference amplifier (V404. The reference voltage from the VR tube appears at the grid of V404A and the fractional sample of the supply voltage at the grid of V404B. The potentiometer labeled "B-HUM LEVEL ADJ", adjusts the hum component on the grid of V404B to a value that causes the grid of V402 to vary just enough to cancel hum from the regulated output.

4 Maintenance

ROUTINE ADJUSTMENTS

Oscillator

Two oscillator adjustments are provided on the chassis rear. The PLATE TUNE adjustment should be set to give maximum negative voltage at pin 7 of V121. The GRID TUNE adjustment controls the frequency of oscillation. The actual oscillator frequency may be determined by forming a Lissajous pattern with the oscillator frequency from pin 2 of V122 and a standard frequency source. Frequency may be more conveniently determined by making an EPUT measurement of a standard 1 MC signal. Before making the EPUT frequency test, the dividers should be tested for alignment as described below.

Dividers

The 1 MC oscillator frequency is divided by 10 seven times to produce the time base outputs. If a divider is scaling by a factor other than 10, the 1 MC test signal will be measured incorrectly at TEST function when using the time base from the misaligned divider or any of the following dividers. Random incorrect readings at TEST indicate a divider which is jittering excessively because it is adjusted on the borderline between division ratios. A slight jitter in one of the first dividers may not produce an incorrect reading in any but the last dividers.

The first six dividers require occasional adjustment by the six potentiometers on the chassis rear lableed DIV. 1, DIV. 2, etc. With the FUNCTION switch at TEST set the MULTIPLIER switch at 10^5 cps. The instrument should read 10. If it does not, adjust DIV. 1 to the middle of the range in which a reading of 10 is obtained. Then set the MULTIPLIER switch to 10^4 cps. A reading of 100 or 99 should appear. If it does not, adjust DIV. 2 to the middle of the range in which either of these two reeadings is obtained. Then set the MULTIPLIER switch to 10^3 and adjust DIV. 3 at the center of the 1000-999 range. In the same manner adjust DIV. 4, DIV. 5 and DIV. 6 in that order.

The adjustment of each divider affects the adjustment of the others slightly. Therefore, after the initial adjustment outlined above, a final adjustment should be made. With the FUNCTION switch at TEST set the MULTIPLIER switch to 10^1 cps. A reading of 100,000 or 99,999 will appear. Adjust in turn DIV. 1 through DIV. 5 to the center of the range in which either of these readings is obtained. Then set

the MULTIPLIER switch at kcps and adjust DIV. 6 to the center of the 1,000,000-999 999 range

If the line voltage to the Model 5510 varies considerably, all the above adjustments should be made while the power input is being varied over the expected range

Negative 60 Volt Supply

Observe the 60 volt hum with a sensitive AC voltmeter or, preferably, an oscilloscope. Adjust the control labeled B-HUM ADJ. to the position producing least hum. Peak-to-peak hum should be less than 0.2 volts.

Positive 100 Volt Supply

Observe supply voltage with an accurate voltmeter. Adjust control labeled B+VOLTS ADJ to produce a reading of 100 volts

TROUBLESHOOTING

Servicing procedures require a vacuum tube voltmeter and a quality oscilloscope. When the instrument fails to function properly first check the power supply voltages for gross variations from the values listed below.

Nominal voltage	Acceptable Hum
+150 volts (unregulated)	15 volts peak-to-peak
-150 volts (unregulated)	15 volts peak-to-peak
+100 volts	.2 volts peak-to-peak
-60 volts	.2 volts peak-to-peak
-100 volts	.2 volts peak-to-peak

The source of most other circuit failures may be quickly traced by comparing the proper circuit waveforms pictured in Figures 10a to d with actual waveforms observed on a suitably triggered oscilloscope It is not sufficient to determine only the presence or absence of a pulse, since pulses must approximate the shape and amplitude shown to properly operate the circuitry A circuit defect may produce an abnormally large pulse which will distrub the operation of the instrument just as much as an inadequate pulse The source of trouble may be traced to one of the major components by observing the waveforms at the input grids of the gate tubes Pulses to be counted appear at pin 1 of V112, start pulses at pin 1 of V114 and stop pulses

at pin 1 of V115. Pulses at these points come from one of the input amplifiers, the time base inverter or the inverter following the Dual Purpose Frequency Divider. The pulse sources at any position of the FUNCTION switch may be determined by referring to Figure 4 and the Schematic Diagram. The pulses seen at the gate tube grids should correspond roughly to proper output waveshapes of the pulse sources as pictured in Figure 10. If an improper waveshape appears, the trouble is in the pulse source. If all waveshapes at the gate tubes are correct the trouble lies in the control circuitry or the DCU's.

When the trouble has been traced to one of the major components consult the typical waveshapes of Figure 10 and the theory section of this manual for guidance in locating the specific difficulty. Tubes, chokes and germanium diodes are the most common sources of trouble. The back resistance of all germanium diodes used in this instrument may drop to 1000 ohms without causing failure. The input amplifiers may be checked conveniently by observing whether or not a pulse is produced as the TRIGGER LEVEL control is rotated from one extreme to the other and back.

Signal paths throughout the Signal Gate and Control Circuits are somewhat more complex than those in the rest of the instrument. The following chart is offered as a guide in locating the source of deficiencies in signal output. Sources are listed left to right from the most immediate to the most remote.

Signal & point of appearance	Source of Signal
Count pulses to first DCU (V113, pin 6)	V113, V112
Reset pulse to DCU's (AY102, pin 3)	V120A, V117, R230, V116 V119, V118, V115
Reset pulse to Dual Purpose Frequency Divider (AY101, pin 8)	T101, V117, R230, V116 V119, V118, V115.
Reset pulse to Latching Binary (T101, pin 1)	T101, V117, R230, V116, V119, V118, V115.
Open-close signal to Signal Gate (V112, pin 7)	V118, V114, V115
Open-close signal to Start Gate, (V114, pin 7)	V119
Delay voltage at Start Gate (V114, pin 2)	V120A, V117, R230, V116, V119, V118, V115.

TROUBLESHOOTING CHART

Symptom

Scattered incorrect readings. Left hand digits of the reading may be stable and correct. TEST reading may be correct on short time bases.

Probable cause

The symptoms above may be due to either of two widely separated failures.

1. A time base divider scaling incorrectly occasionally. First this possibility should be checked by readjusting the dividers.

2. Failure of one of the DCU's. A DCU with boderline characteristic tubes may scale correctly for the first few milliseconds of each counting period before becoming erratic. Faulty operation may be confined to a particular input frequency range. Over this range stable correct readings may be obtained on short time bases only. Failure of the first DCU (AY101) may be due either to DCU components or a faulty drive signal from V113 and V112.

Symptom

Instrument will not start counting.

Probable cause

Faulty Signal Gate Control binary (V118), or Start Gate tube (V114) or fault in source of start pulses.

Symptom

Instrument will start counting but will not stop.

Probable cause

Faulty Gate Control Binary or Stop Gate tube or fault in source of stop pulses.

Symptom

Incorrect readings at PERIOD x10 and 10X/Y functions and at 10 second time base only.

Probable cause

Faulty DCU AY107 or drive tube V111A.

Symptom

Incorrect readings at PERIOD x 10 and 10X/Y functions only.

Probable cause

Failure of V110A or open inductor L105.

Symptom

Input channel triggers pulses erratically when its TRIGGER LEVEL control potentiometer is rotated.

Probable cause

Defective potentiometer.

Symptom

Incorrect TEST readings on short time bases.

Probable cause

Failure of V120A.

Symptom

Instrument will not reset.

Probable cause

Failure of V117 or V116.

Symptom

Instrument inoperative. No negative supply voltages. Power supply resistor R409 burned out.

Probable cause

One of the DCU's, AY101 to 106, may have been replaced by a DCU which is not one of the "G" series, that is, 707AG or 705AG.

Symptom

Signal gate fails to remain open for full time base period at TEST with certain MULTIPLIER switch settings.

Probable cause

Failure of V120B.

5 Parts list

Detail No.	Stock No.	Description	Mfr. & No.
		CHOKES	
L101	3-3183	250μh	Carad
L102 - L103	3-3560	5mh Ferrite Core	Carad
L104	3-3347	750μh	Carad
L105 - L106	3-3560	5mh Ferrite Core	Carad
L107 to L110	3-3183	250μh	Carad
L111	3-2422	30mh	Miller 683
L112	3-3347	750μh	Carad
		TUBES	
V101 - V102	5-0573	12AT7	
V103	5-2526	6U8	
V104	5-0573	12AT7	
V105	5-0746	6AH6	
V106	5-2129	5687	
V107	5-0573	12AT7	
V108	5-0746	6AH6	
V109	5-2129	5687	
V110	5-2362	5963	
V111	5-2526	6U8	
V112	5-0500	6AS6	

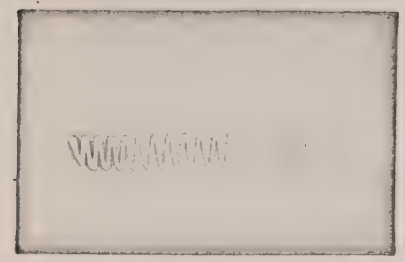
Detail No.	Stock No.	Description	Mfr. & NO.
V113	5-2526	6U8	
V114-V115	5-0500	6AS6	
V116	5-2362	5963	
V117	5-1893	2D21	
V118 to V121	5-2362	5963	
V122	5-2129	5687	
V123	5-3301	5965	
V124 to V127	5-2362	5963	
V401	5-0550	6AU6	
V402	5-2625	6080	
V403	5-0531	OB2	
V404	5-0556	6J6	
		TRANSFORMERS	
T101	6-3858	Pulse Transformer	Triad PL-5 or Eqiv. by Carad
T102-T103	6-3857	Pulse Transformer	PCA-101-2 Equiv. by Carad
T401-T402	6-3853	BSC Spec.	Electro
		FUSES	
F401-F402	7-3215	5A-125 V SLO BLO	Littlefuse 313005

Detail No.	Stock No.	Description	Mfr. & No
		RECTIFIERS	
CR101-CR102	8-0668	1N34A	Kemtron
CR104	8-0668	1N34A	Kemtron
CR401-CR402	8-3852	Selenium Bridge per Spec. Dwg.	
		SWITCHES	
S101	12-3854	Attenuator Special (Including R116)	BSC Spec.
S102	12-3854	Attenuator Special (Including R145)	BSC Spec.
S103	12-3854	Attenuator Special (Including R173)	BSC Spec
S104	12-1641	SPDT Toggle	CH 8282K13
S105	12-1909	DPDT Toggle	CH 8373K7
S106	12-3856	Time Base Switch	BSC Spec. Centralab
S107	12-3855	Function Switch	BSC Spec. Centralab
S108	12-1643	SPST Toggle	CH 8280K15
S109		Switch Plate SPDT on back of 10 M Pot. R230	
S110	12-0879	Push Button Micro-switch	
S401	12-1642	DPST Toggle	CH 8270K8

Detail No.	Stock No.	Description	Mfg. & No.
		MISCELLANEOUS	
B401	9-3389	Motor 6" Blade	General Industries A-9-CW
Y101	13-3884	Crystal 100 KC, 115V, Heater	
J101 to J105	17-3179	Receptacle	IPC MS 595
J106	17-5620	Connector 40 Pin	Cannon DPX 40 34S

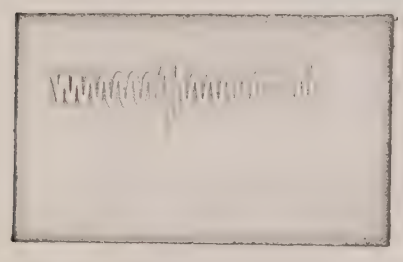
NOTE

The following photographs
were taken from a Model 511AD
Tektronix oscilloscope.

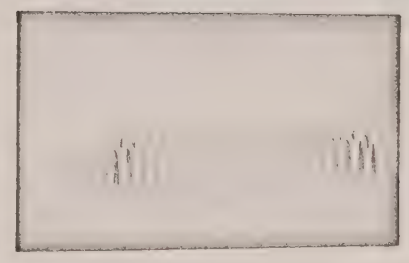


1. Oscillator output.
V121, pin 6.

2. 1 MC TEST pulses from shaper.
V122, pin 3.

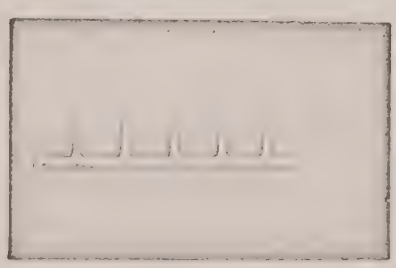


3. Output of shaper.
V122, pin 9.



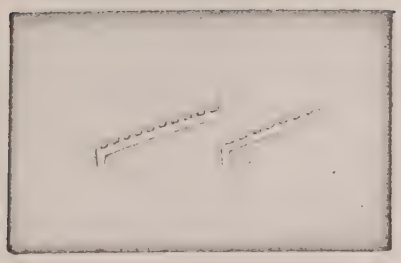
4. 10^{-6} time base signal.
V122, pin 1.

5. Input grid of 1st divider.
V123, pin 2.

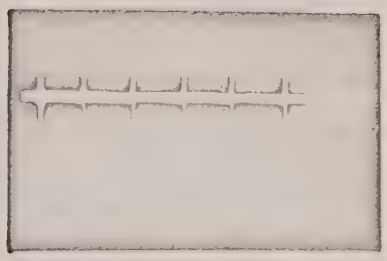


6. Output of first divider.
V123, pin 3.

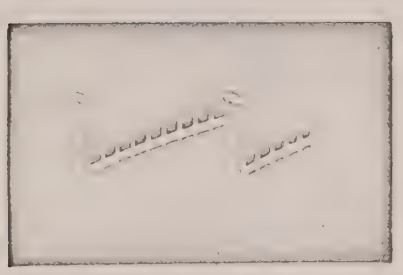
Figure 10a Typical Waveforms



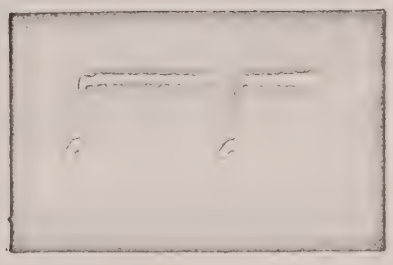
7. Input grid of 1st divider.
V123, pin 7.



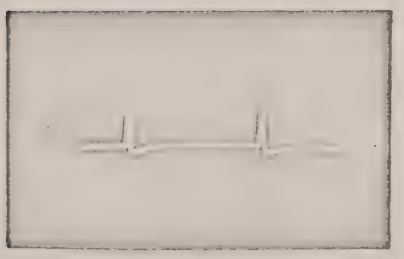
8. Output of 2nd divider.
V123, pin 6.



9. Input grid of 3rd divider.
V124, pin 7.



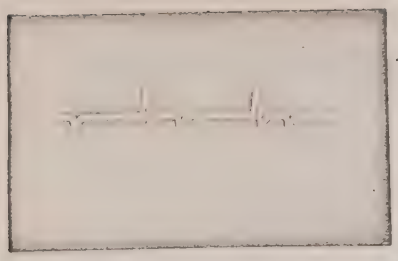
10. Output of 3rd divider.
V124, pin 6.



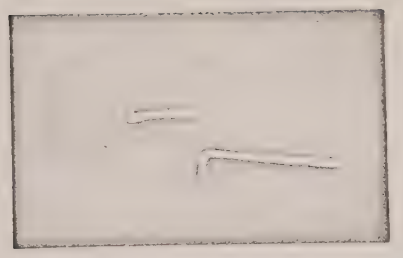
11. Time base inverter output.
V114, pin 1
MULTIPLIER switch at 10^{-5}.
FUNCTION switch at EPUT.

12. Output of Y Amplifier.
V114, pin 1.
FUNCTION switch at PERIOD.

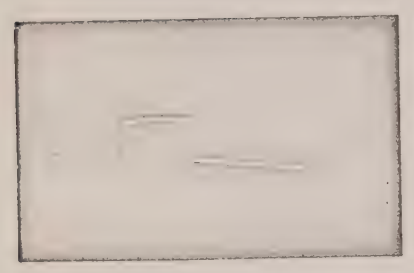
Figure 10b Typical Waveforms



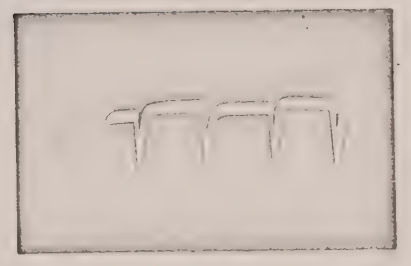
13. Output of X Amplifier.
V103, pin 1.



14. Signal gate open-close signal.
V112, pin 7.
Measure voltages with VTVM.

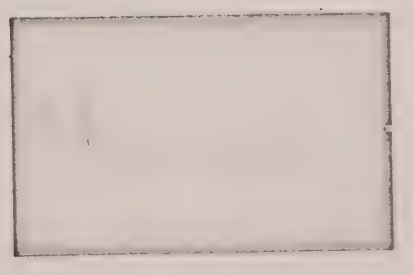


15. Start gate open-close signal.
V114, pin 7.
Measure voltages with VTVM.



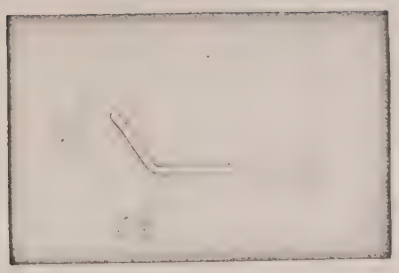
16. Count pulses to 1st DCU.
V113, pin 6.
FUNCTION switch at PERIOD.
MULTIPLIER switch at 10^{-5}.

17. Reset pulse to DCU's.
AY 102, pin 3.

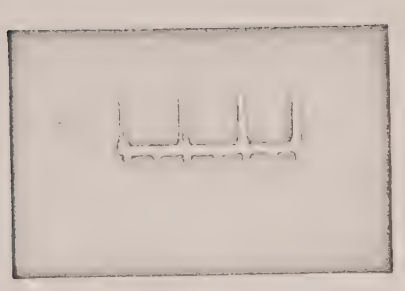


18. Reset pulse to binaries.
T101, pin 1.

Figure 10c Typical Waveforms



19. Start gate delay pulse. V114, pin 2.



20. Output of inverter V110B following Dual Purpose Frequency Divider. V110, pin 6. Y Amplifier output being divided.

Figure 10d Typical Waveforms

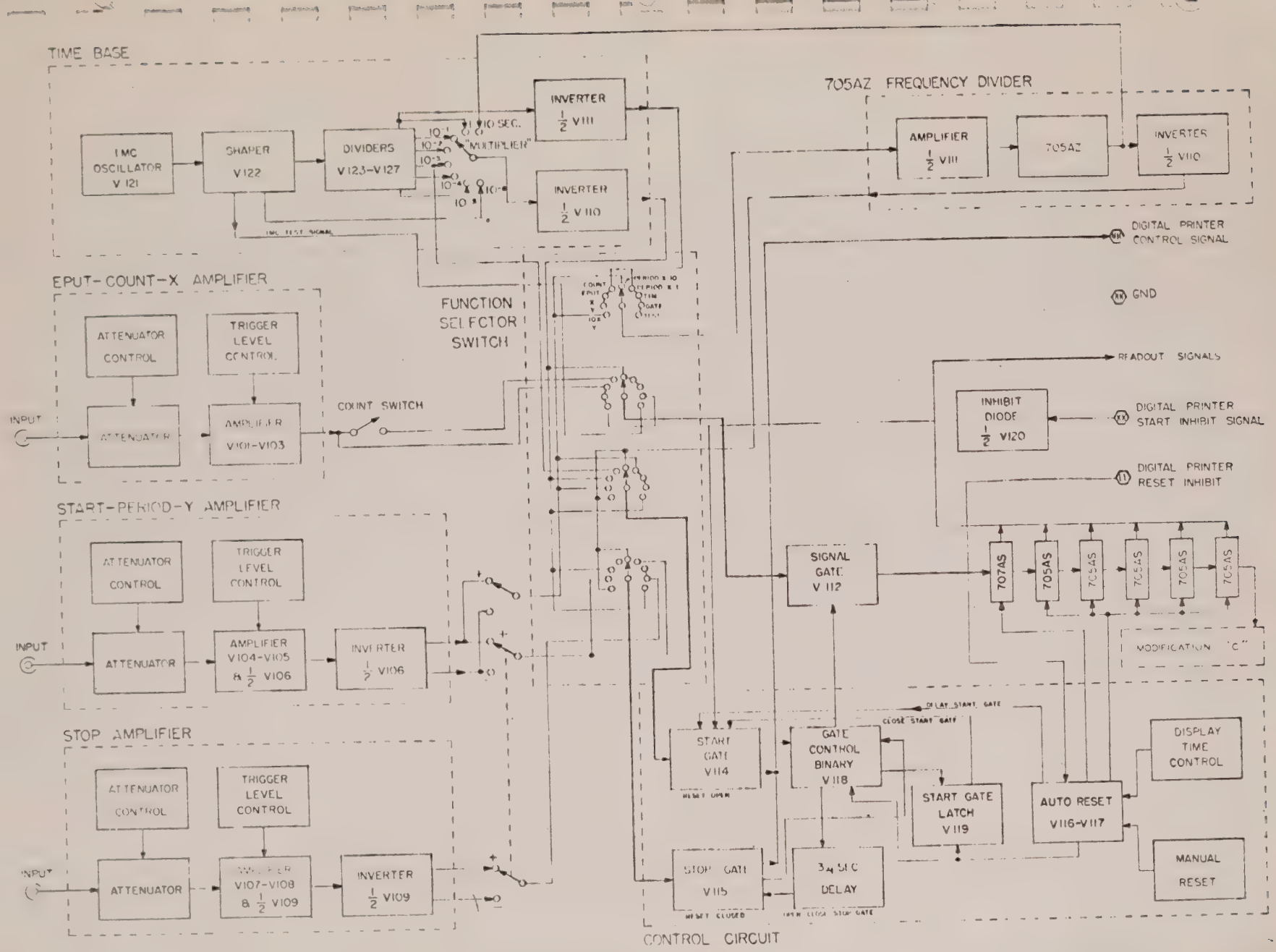


Figure 11 Block Diagram, Model 5510

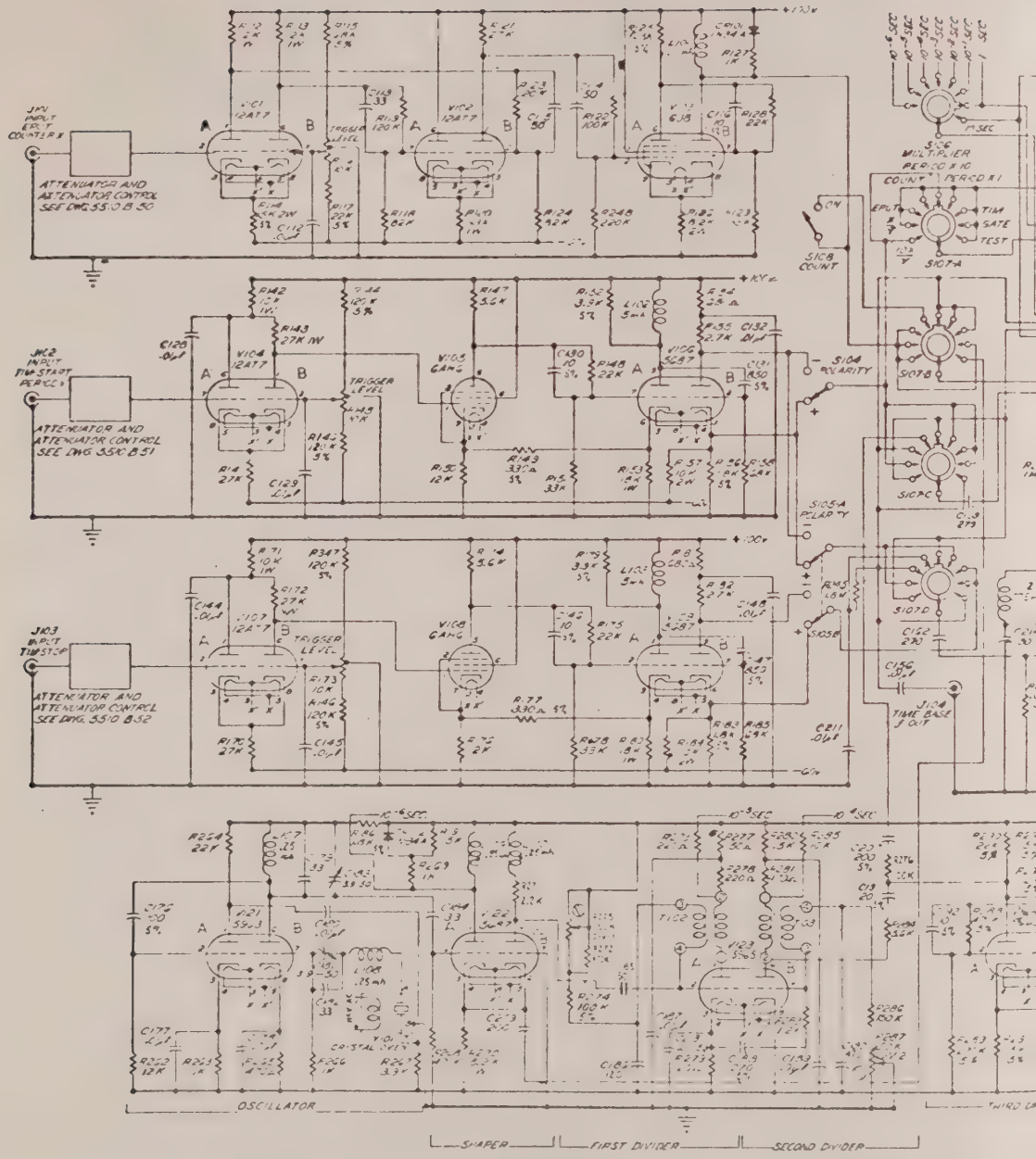
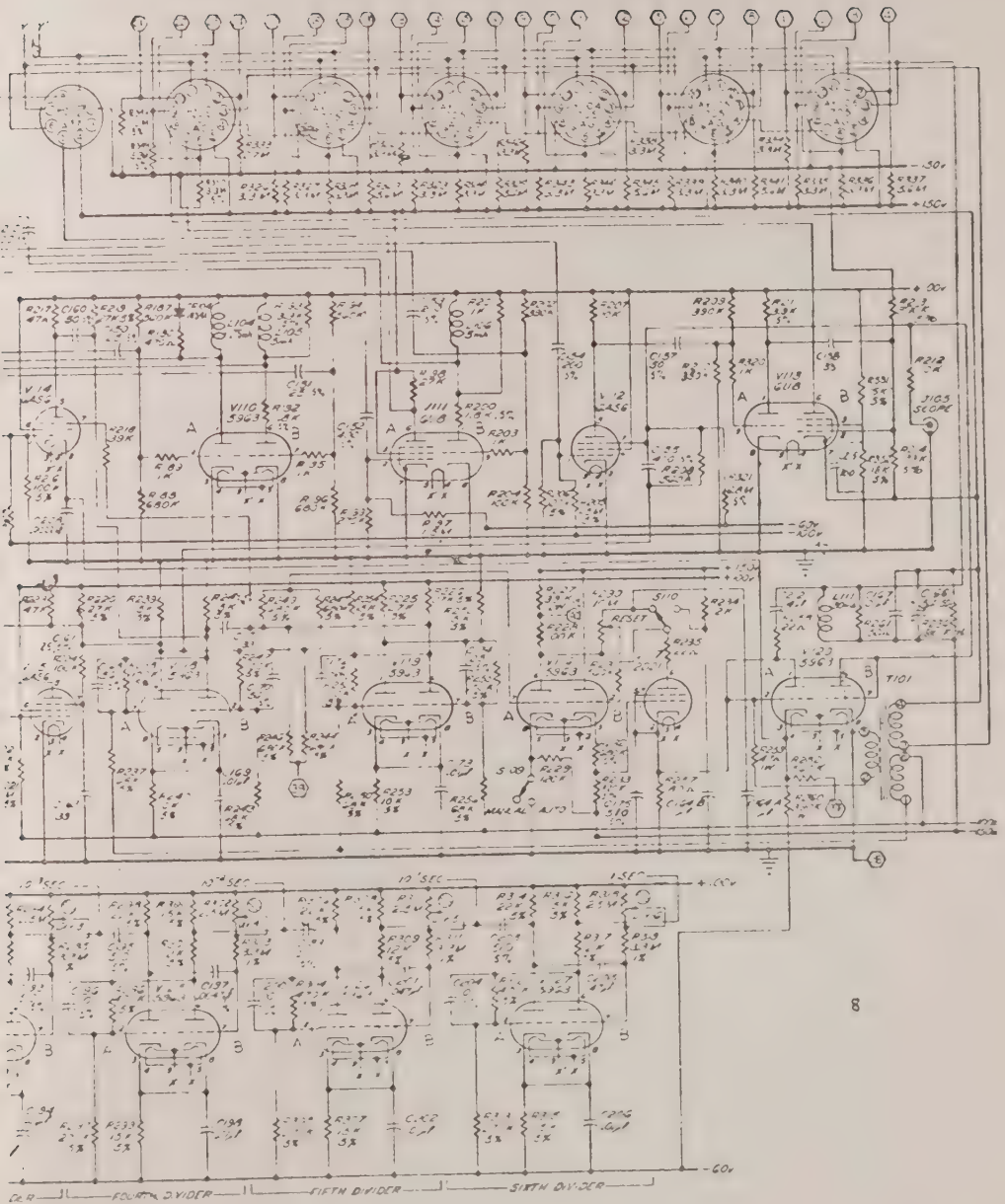
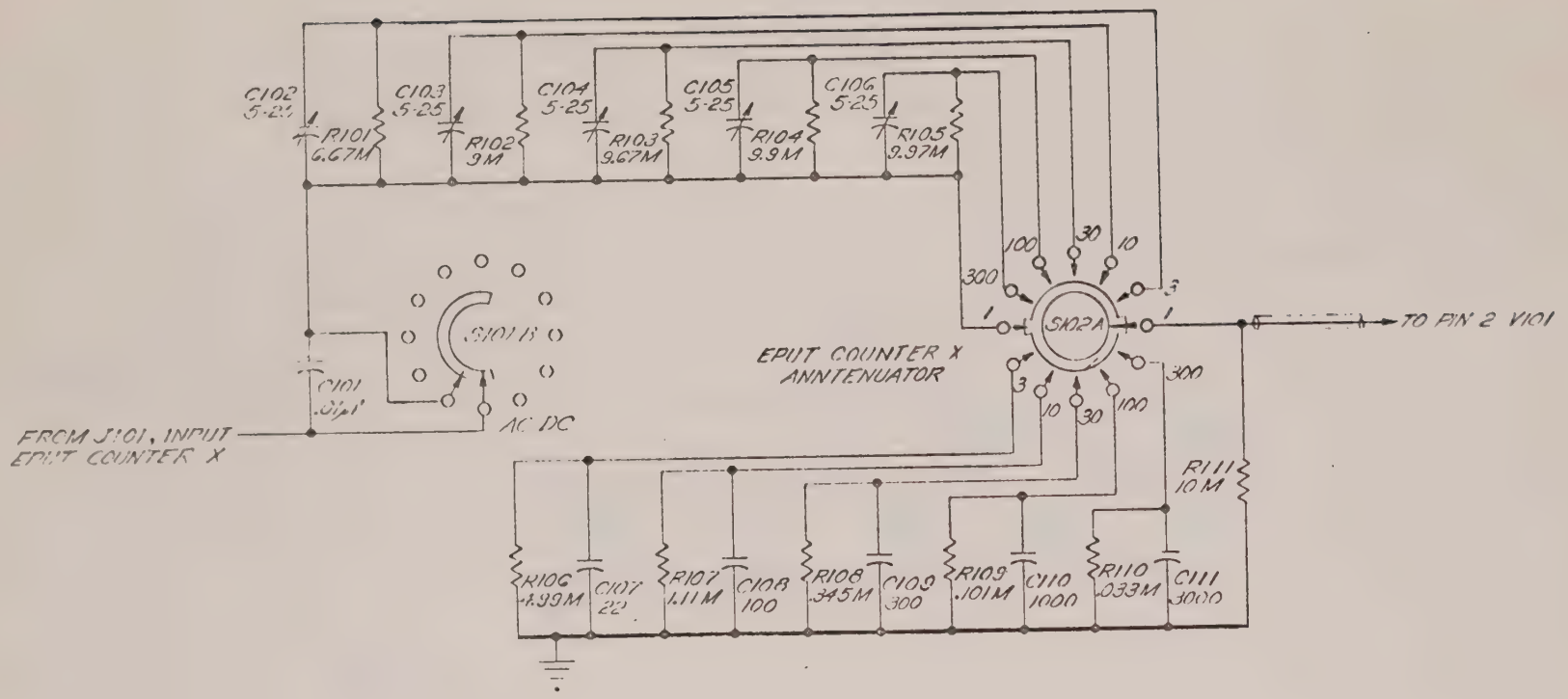


Figure 12 Schematic Diagram, Model 5510



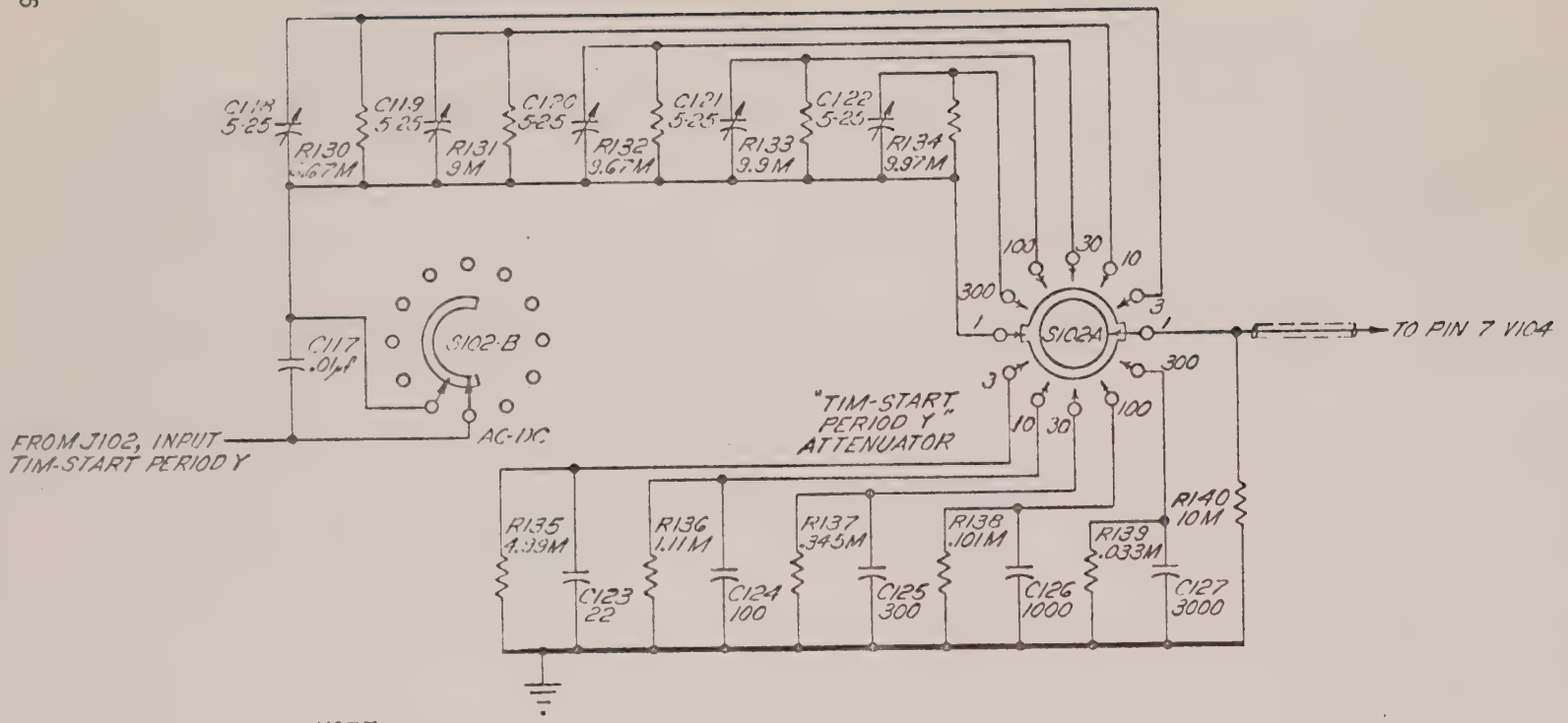
NOTE:
RESISTORS
WATTAGE ——— ½W UNLESS OTHERWISE NOTED.
TOLERANCE ——— 10%
CAPACITORS
CAPACITY ——— IN mfd
VOLTAGE RATING — 500v

○ —DENOTES PIN CONNECTIONS TO J106 (DIGITAL RECORDER SOCKET).



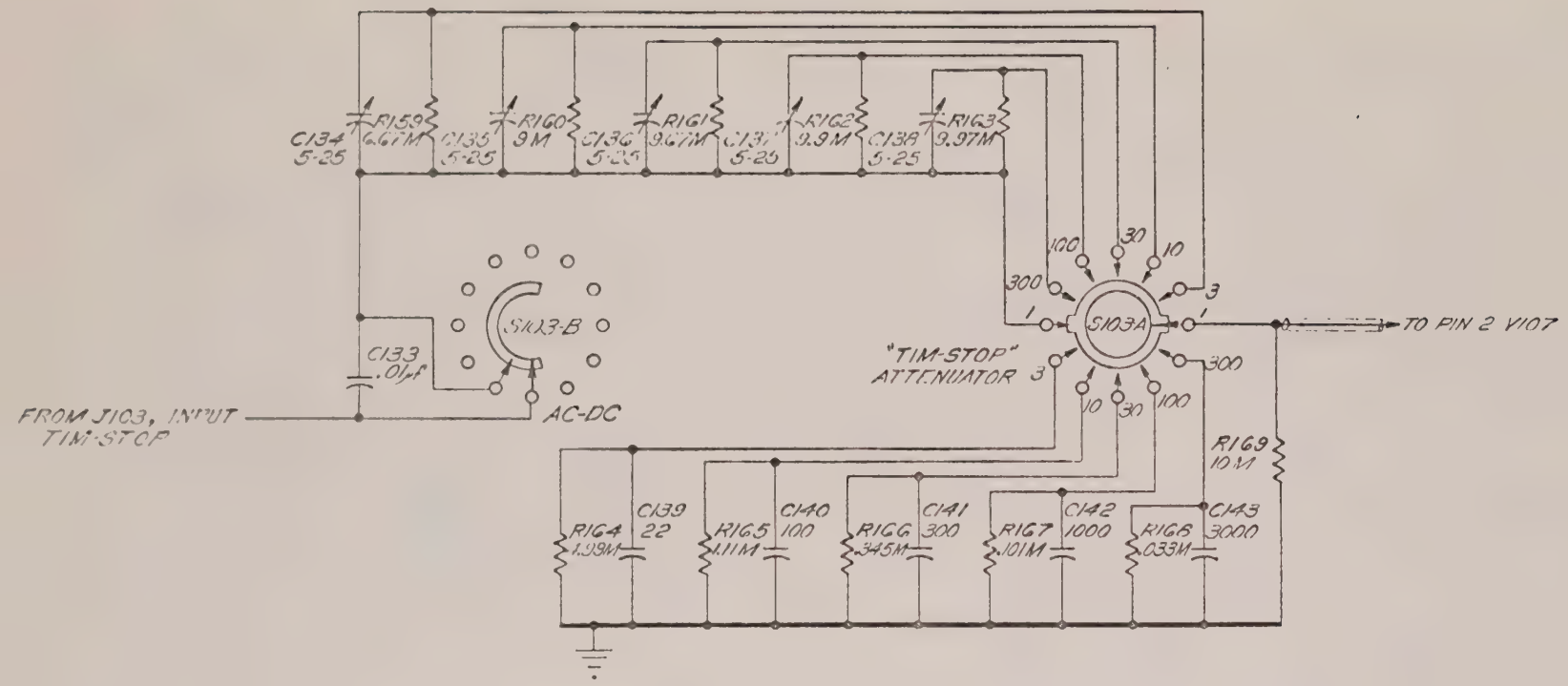
NOTE:
RESISTORS
WATTAGE ½W.
TOLERANCE 1%.
CAPACITORS:
CAPACITY IN µµf UNLESS NOTED OTHERWISE.
VOLTAGE RATING 500v.

Figure 13 X Channel Attenuator Schematic



NOTE:
RESISTORS:
WATTAGE ½ WATT.
TOLERANCE 1%.
CAPACITORS:
CAPACITY IN μμf UNLESS NOTED OTHERWISE.
VOLTAGE 300v.

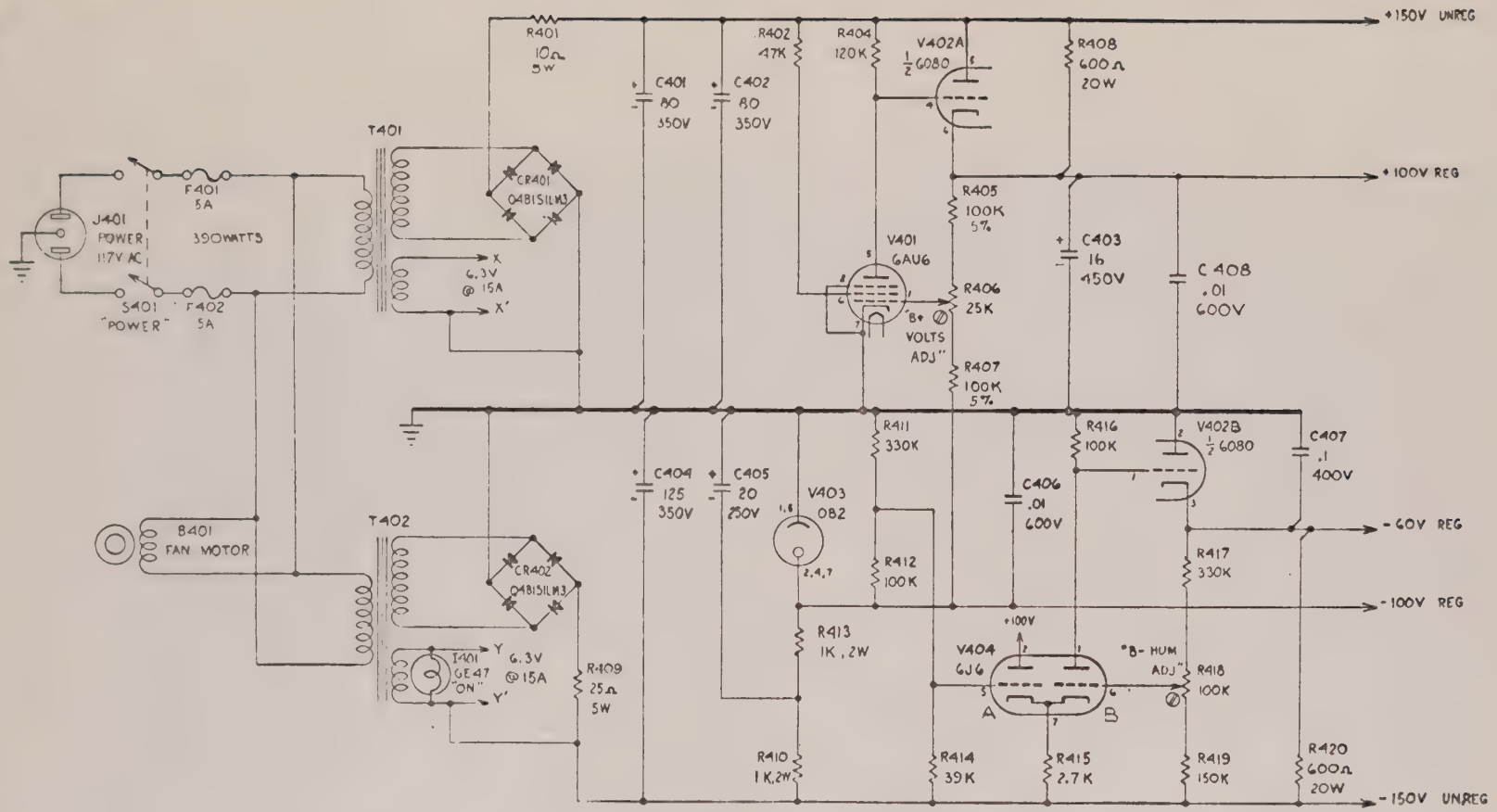
Figure 14 Y Channel Attenuator Schematic



NOTE:
RESISTORS:
WATTAGE — ½ WATT.
TOLERANCE — 1%.

CAPACITORS:
CAPACITY — IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE — 500v.

Figure 15 Stop Channel Attenuator Schematic



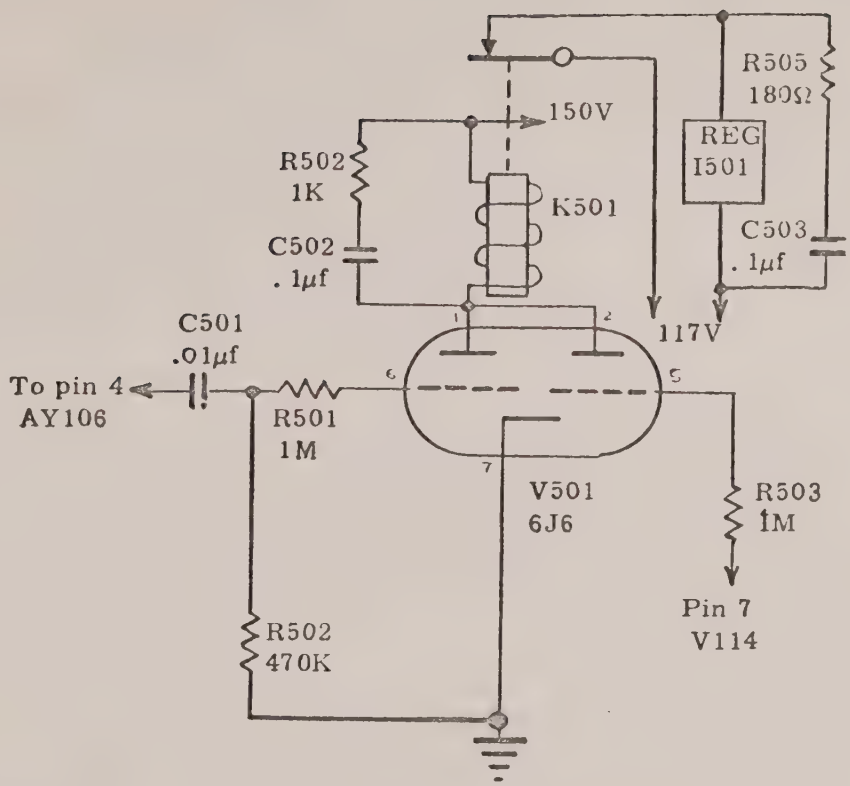
NOTE:
UNLESS NOTED OTHERWISE;
1- ALL RESISTORS 1/2 W ±10%
2- ALL CAPACITOR VALUES IN μfd.

Figure 16 Power Supply Schematic, Model 5510

MODIFICATION C

Modification C adds a drive circuit for a six digit mechanical register which extends the capacity of the Model 5510 to one trillion (10^{12}) counts Figure 17 shows all the added circuitry except the resistor referred to in the note below the diagram. The register drive circuit consists of V501 and relay K501. The contacts of K501 are open when the relay is energized A negative pulse generated by the sixth decade counter (AY 106) momentarily stops current flow in the tube de-energizing K501 and causing its contact to " make". The contacts energize the register causing it to record one count for each 10^6 input pulses. The register must be manually reset by the thumb wheel.

The sixth decade may generate a negative pulse when the instrument is reset. The register is prevented from counting such a pulse by the action of the right half of V501. Pin 5 of this tube goes positive between the occurrence of the reset pulse and the start of counting. The positive charge on the grid attached to pin 5 causes current to flow in the relay at resetting even though a negative pulse is received on grid 6. Therefore, the negative pulse does not affect the relay.



NOTE: A 12,000 ohm resistor R501 is shunted across R234 from the manual RESET button to the +150 volt supply.

Figure 17 Schematic Diagram, Modification C

INSTRUCTION
MANUAL

Model 705 AZS

DECIMAL COUNTING UNIT

BERKELEY division
Beckman Instruments, Inc.

Richmond 4, California
20 November 1954

The Model 705AZS, Decimal Counting Unit, has been designed especially for use as a scale-of-ten extension to time bases. Its schematic is essentially that of the 705A except for three modifications (see Figure 1).

1. The voltage on the right hand plate of the last binary (pin 1 of V104) is led out to pin 3 of the DCU socket. Pin 8 on the DCU socket is connected to pin 6 on V104.

2. Pin 2 of the DCU socket is not grounded. Voltages at all points in the Model 705AZS are 150 volts negative of voltages at the same points in the Model 705A.

3. The 705AZS is returned to the "nine" condition by the Reset control This is done by connecting the reset line

A DCU reset at "nine" requires only one input count to generate an output and commence a new timing cycle. A DCU reset at "zero" would require ten input counts before transmitting a Start pulse to the gating circuitry.

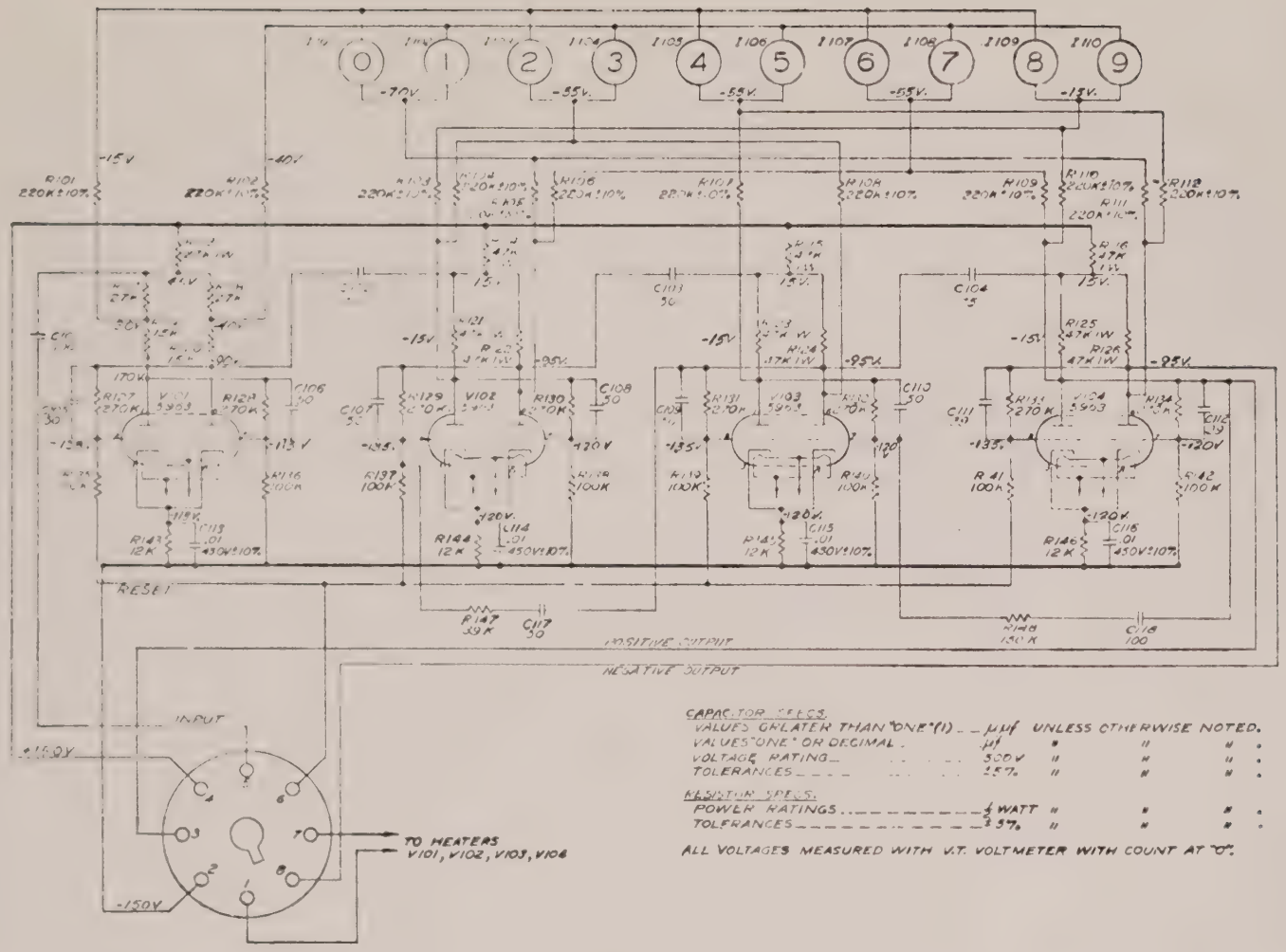


Figure 1 Schematic Diagram, Model 705AZS

INSTRUCTION
MANUAL

Lot 27 and up
Appendix A

Model 705A
Decimal Counting Unit

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
1 May 1954

CONTENTS

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	Installation	
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Section 3	Theory of Operation	3
	Basic Design	
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ILLUSTRATIONS

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Figure 1 Model 705A Decimal Counting Unit

Section 1
INTRODUCTION

The Model 705A Decimal Counting Unit (DCU) is a direct reading, plug-in electronic counter. The number of counts received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. Any number of units can be connected in cascade (the output of one unit driving the next) to form a counter whose total capacity depends only on the number of DCU's. Thus, five units will count to 99, 999 and reset to 00,000 on the 100, 000th pulse.

Specifications

Count Indication	Direct Reading Decimal presentation
Power Requirements	Heater: 6.3 v. at 1.2 amps Plates: 300 v. at 15 ma.
Input Requirements recommended	Negative pulse 100 volts peak amplitude
Rise Time	Less than 1 μsecond
Duration	At least 2 μseconds
Output Characteristics	Designed to drive a Model 700A, 705A, or 707A
Resolution of Paired Pulses	5 μseconds
Reset to Zero	Instantaneous through opening of grid return
Maximum Counting Rate	100, 000 cps
Construction	Plug-in unit octal socket
Dimensions	1-3/8" x 5-1/2" x 5-1/2"
Weight	1 lb.
Tubes	Four type 5963

Section 2

OPERATION

Installation

Normally, Decimal Counting Units are installed in Berkeley instruments. No special instructions are necessary. For unusual installations, we invite your inquiry.

Operation

Power requirements:

Plates: 225 to 400 volts (nominal 300 volts at 15 ma.)
Filaments: 6.3 volts at 1.2 amperes.

Input requirements:

If the Model 705A is powered by an unregulated supply, the drive amplitude should vary with the supply voltage. A negative transient is required to drive the unit, either a square wave or a rectangular pulse at least 2 microseconds wide. The pulse amplitude depends on the rise time. For a rise time of 0.5 microseconds (measured between ten and ninety percent values), the pulse amplitude should be between 75 and 135 volts; for a 2 microsecond rise time, an amplitude of 120 to 165 volts should be used. Rise times of 1 microsecond or less, pulse amplitudes of 100 volts, and a 300 volt supply offer optimum performance. The input load presented by either unit during triggering is equivalent to 100 $\mu\mu$f in series with 15,000 ohms.

Output requirements:

The output is a rectangular waveform presented at the output terminal as a change in d-c voltage (see Figure 4). Between "0" and "6", the output is 55 volts; "6" and "7", 125 volts; and "8" and "9", 135 volts. The step between "7" and "8" is caused by an interpolation network.

The load imposed on either unit must not be more than 300 K to ground or 6 K in series 100 $\mu\mu$f.

Section 3
THEORY OF OPERATION

Basic Design

The basic circuit of the Model 705A is a modification of the Eccles-Jordan trigger circuit with two stable states, referred to as a binary. It is a two-stage amplifier with the output of the second stage connected to the input of the first, as shown in Figure 2.

With no input, the loop gain is less than one, and the circuit is in one of its two stable states, i.e., either V2 conducting and V1 cut off, or vice-versa. The circuit is triggered from one state to the other by making the loop gain greater than one. The binary is coupled to a single trigger source through C1 and R1 in such a way that the effect of the trigger is different on the two stages, depending on which stage is conducting. For example assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through the cross-over network (R5, R8, C3 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. When the input pulse is of sufficient amplitude, the loop gain becomes greater than one, and the binary is triggered to its other stable state, V1 conducting the V2 cut off. The next input pulse reverses the process and causes the binary to return to its original state. Thus, the binary completes a cycle for every two input triggers, and is a scale of two. By a cascade arrangement of binaries, a counter having a scale of any power of two can be obtained.

Circuit Analysis

Four binaries are connected in cascade forming a scale of 16, which is permuted to a scale of 10 by two resistor-capacitor "feedback" networks (see Figure 3).

The circuit operates as a conventional binary counter up to the count of four. On the count of four the third stage is triggered, sending a pulse through the first feedback network, thereby triggering the second stage. Since it requires two inputs to trigger the second stage, this is the equivalent of adding two input pulses and the unit now corresponds to a binary count of six. On the count of six (which is the equivalent of eight in a binary counter) the fourth stage is triggered, sending a pulse through the second "feedback" network and triggering the third stage. This is the same result as if four additional input pulses had been applied and the unit has a binary

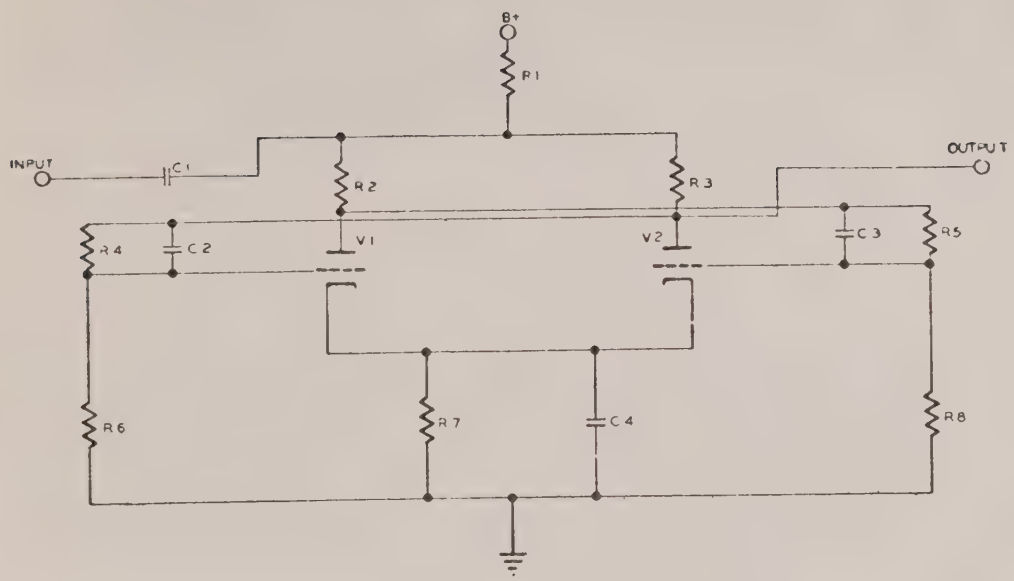


Figure 2 Basic Circuit

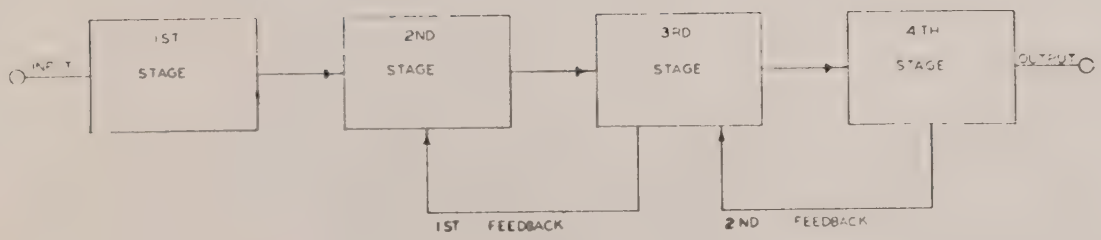


Figure 3 Functional Diagram

count of twelve stored in it. The unit again operates as a binary scaler for the remaining four pulses required to reset it to zero. Therefore, by adding the equivalent of six input pulses, the scale-of-16 has been permuted into a scale-of-10.

Section 4
MAINTENANCE

When a Decimal Counting Unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Since the counting unit is usually the indicating device of a larger instrument, faulty operation is often ascribed to it when the symptoms of external faults are displayed.

Troubleshooting

Two methods are recommended for finding the trouble in a faulty counting unit. First, by observing the lighting sequence while driving the unit at a slow repetition rate, and second, by studying the waveform of each stage while driving the unit at a repetition rate fast enough to be conveniently viewed on an oscilloscope. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. Table 1 lists common troubles. Faulty tubes cause most failures.

Diagrams and Tables

Typical waveforms are shown in Figure 4. By comparing these with the waveforms from a defective unit, the faulty stage can be quickly detected. Table 2 lists the voltages and resistances between tube socket connections and ground so that, in conjunction with the schematics and parts location diagrams, all information necessary to maintain the equipment in proper working order is available. It should be remembered that the values given are nominal, and considerable variations may be encountered owing to various line voltage conditions and component tolerances.

Circuit drawings and parts location diagrams will be found at the rear of the manual. The voltages shown were obtained with a vacuum tube voltmeter, a supply voltage of 300 volts, and measured between ground and the point indicated. The unit must be reset to zero to obtain the values shown.

Table 1
COMMON TROUBLES*

Symptom	Cause
Unit Fails to Count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude. (c) Input signal of wrong polarity (d) First stage inoperative.
Unit Counts Spuriously	(a) Stray output signal. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Unit Counts Erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit Fails to Reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component
Unit Counts in Wrong Sequence (the pattern of lighting is repeated after a definite number of input pulses. One or more lights may be "On" simultaneously during a cycle provided that the number of states per cycle remains constant).	
1. Unit skips every other number.	(a) First stage defective. (b) Input circuit supplies double pulses.
2. Two stable states per cycle.	(a) Second stage defective (count can be 01 or 45). (b) Loss of drive to second stage (01).
3. Four stable states per cycle.	(a) Third stage defective (count can be 0123 or 6789). (b) Loss of drive to third stage (0123).

4. Six stable states per cycle.	(a)	Output excessively loaded (count can be 012345-012345).
	(b)	Last stage inoperative (count can be 01234501 etc. or $67^{89}_{23}89$. The count $\frac{8}{2}$ indicates both "8" and "2" lamps are on.
	(c)	Loss of drive to fourth stage (count can be 012345).
5. Eight stable states per cycle or any failure where two successive numbers are skipped.	(a)	Second or third stage failure.
6. Ten stable states per cycle, but the lighting sequence is incorrect.	(a)	Where the "0" neon lamp lights instead of the "4", the trouble is with either the "0" or "4" lamp, and in the majority of cases it is "4". This can happen on any count; zero and four were used as examples. It is also possible that more than one lamp may light in place of, or with the one that fails.
7. Twelve stable states per cycle.	(a)	When lighting sequence is 012345456789^{01}_{0}-0, etc. (The count 4 indicates both "0" and "4" lamps are on). First feedback failure. Second or third stage losing emission.
	(b)	When the lighting sequence is 012345678989^{23}-0, etc. Second feedback failure. Third or fourth stage losing emission.

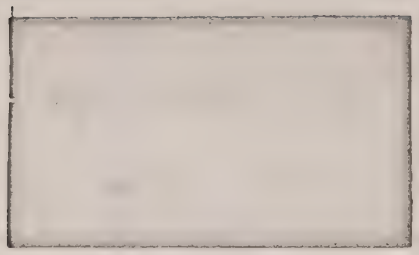
* Reset Unit before troubleshooting.

Table 2
MODEL 705A - VOLTAGES & RESISTANCES

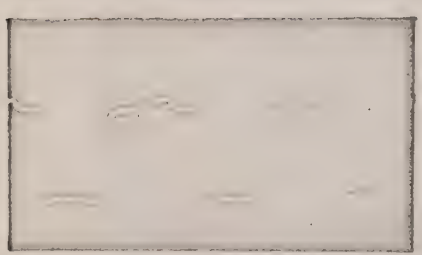
Tube	Pin No.	D.C. Voltage to Ground	Resistance to * Ground (in ohms)
V101	1	170	105K
	2	17	85K
	3, 8	37	12K
	4, 5, 9	Filaments	
	6	60	105K
	7	37	85K
V102	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K
V103	1	135	100K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	100K
	7	30	83K
V104	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K

* When making the above resistance measurements on a DCU with an octal plug, connect pin 2 to pin 6. On a DCU with an 11 pin plug, connect pin 3 to pin 8.

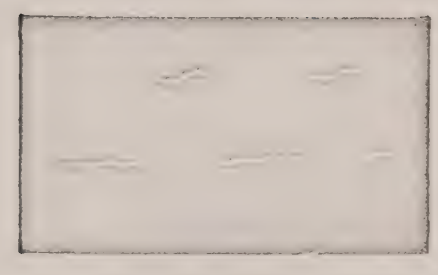
A. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 20Kc.



B. Second Stage, Pin 6, V102, UVL + 140, LVL + 55, frequency 20 Kc.

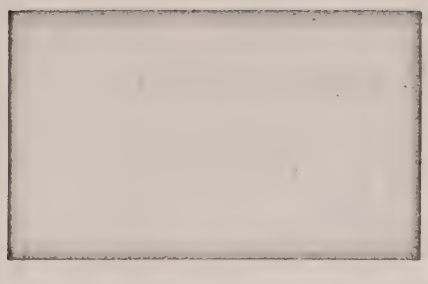


C. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 20 Kc.



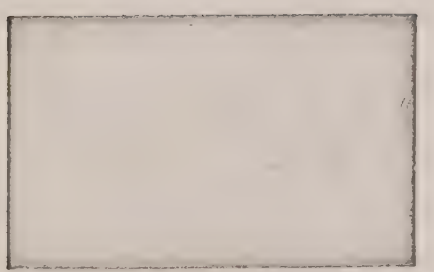
D. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 20Kc.

Figure 3 Typical Waveshapes

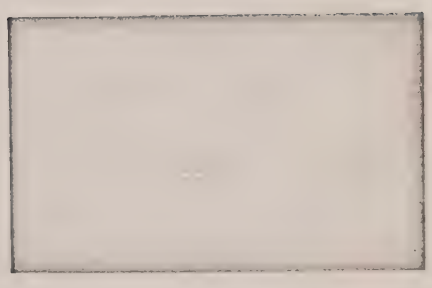


E. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 100Kc.

F. Second Stage, Pin 6, V102, UVL 140, LVL + 55, frequency 100Kc.

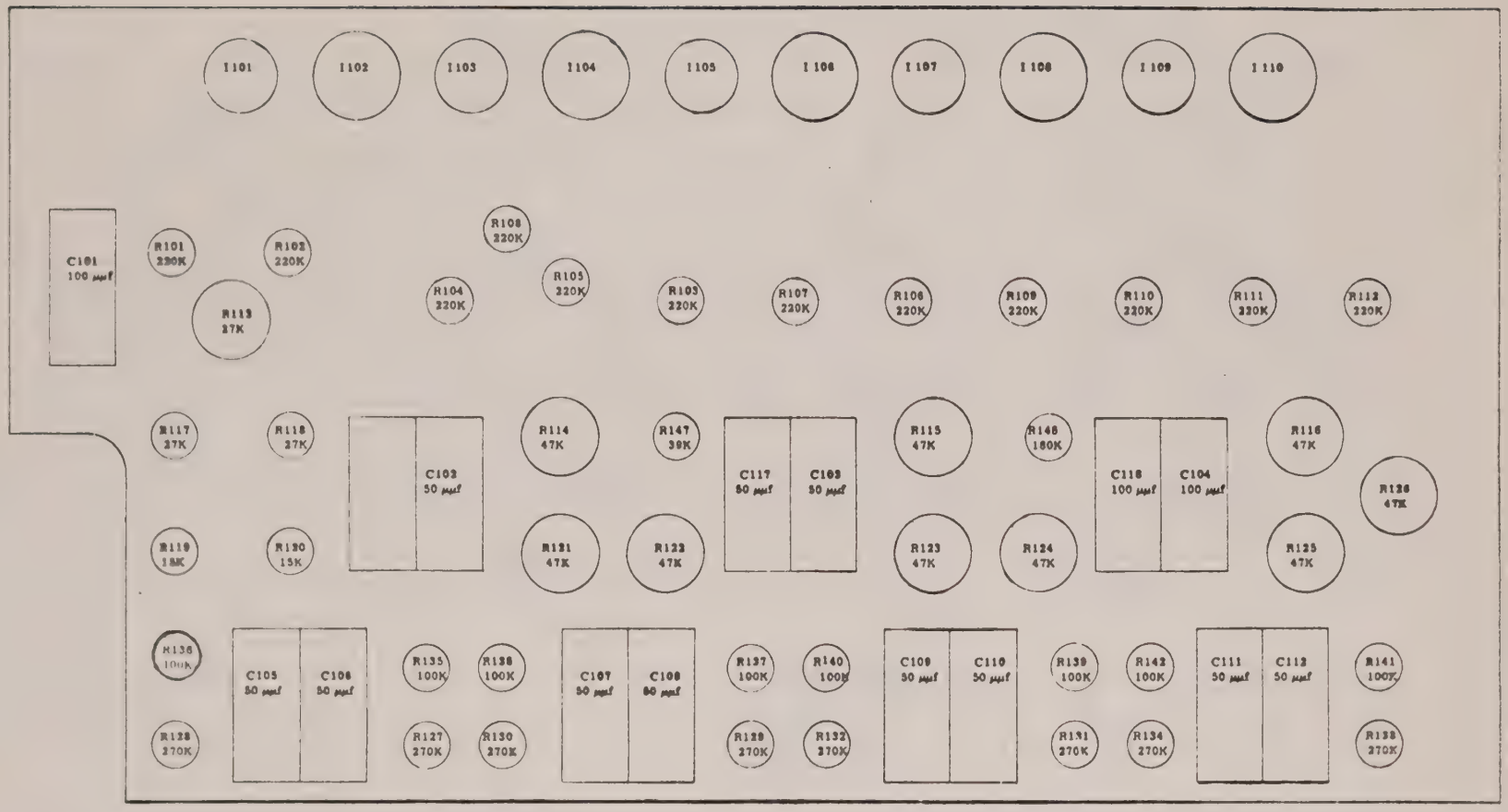


G. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 100Kc.

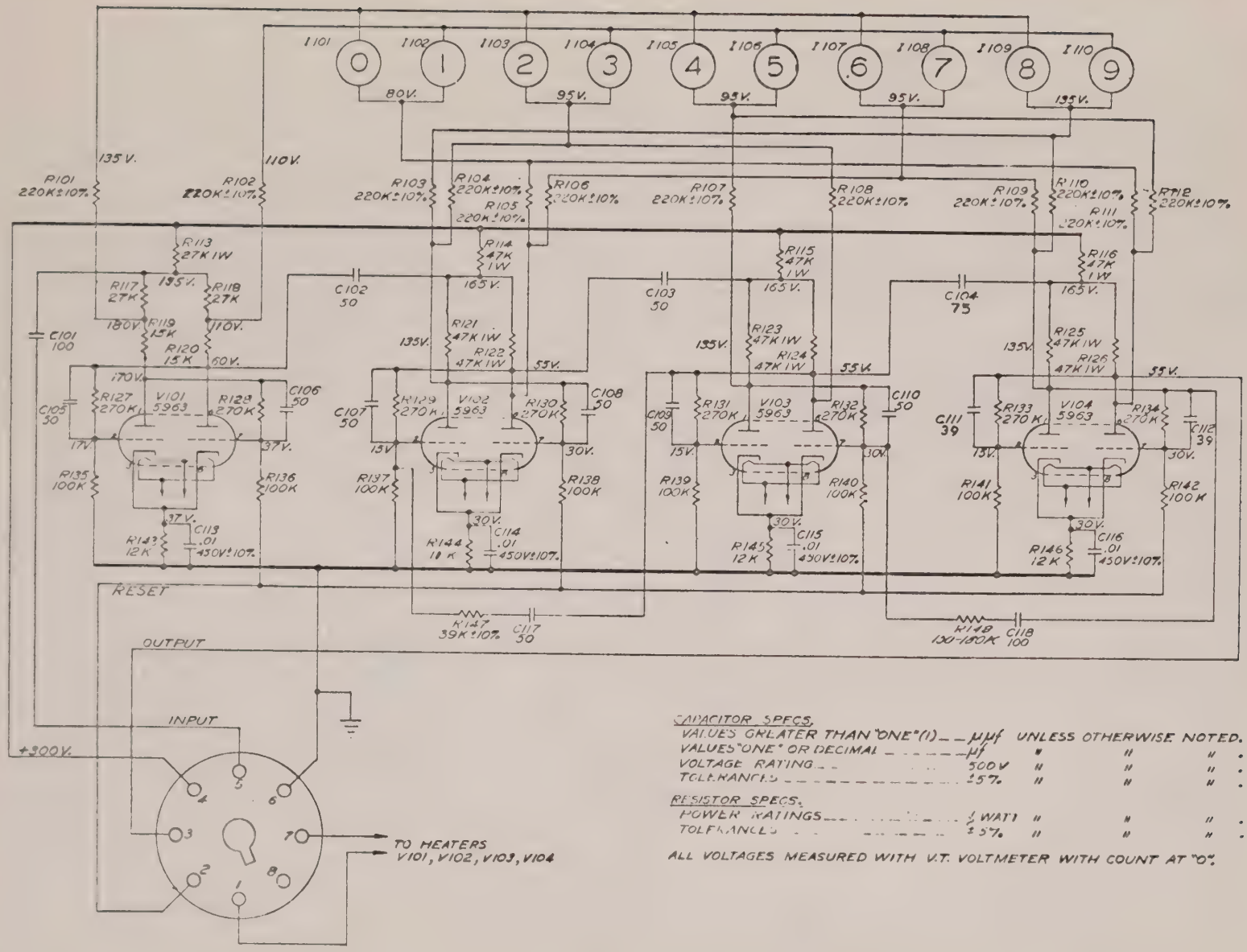


H. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 100 Kc.

Note: UVL = upper voltage level
LVL = lower voltage level
All waveforms are blanked.



Parts Layout



CAPACITOR SPECS.

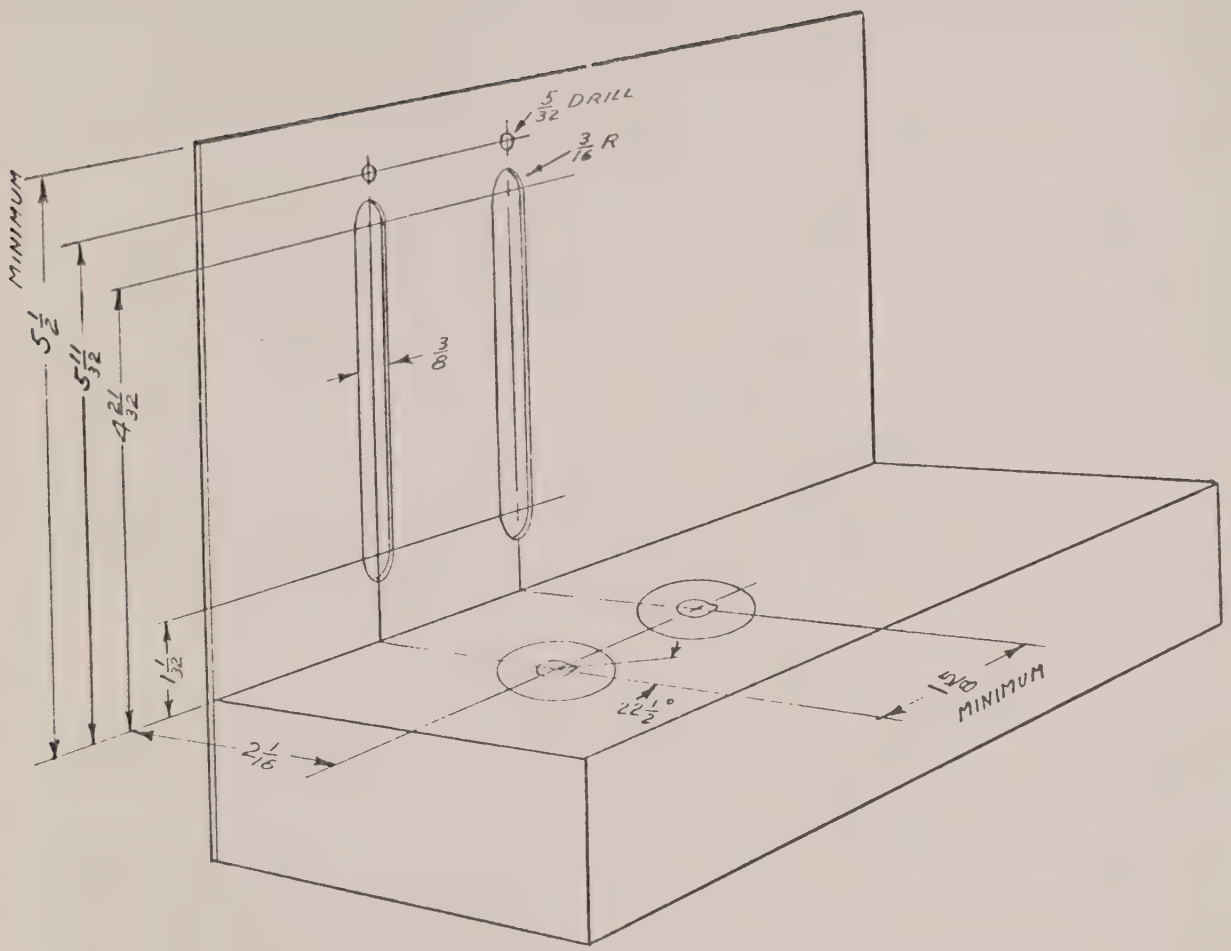
VALUES GREATER THAN "ONE" (1)	μμf	UNLESS OTHERWISE NOTED.		
VALUES "ONE" OR DECIMAL	μf	"	"	"
VOLTAGE RATING	500V	"	"	"
TOLERANCES	±5%	"	"	"

RESISTOR SPECS.

POWER RATINGS	½ WATT	"	"	"
TOLERANCES	±5%	"	"	"

ALL VOLTAGES MEASURED WITH V.T. VOLTMETER WITH COUNT AT "0".

Figure 6 Schematic Diagram Model 705A



NOTE: Dimensions are based on the use of an Amphenol "MIP" 8 or 11-pin socket and .064 metal in the chassis.

Mounting Dimensions, Model 705A

INSTRUCTION
MANUAL

Model 705AG
DECIMAL COUNTING UNIT

BERKELEY division of
Beckman Instruments, Inc

Richmond 4, California
20 November 1954

The Model 705AG Decimal Counting Unit is identical to the Model 705A DCU except for two modifications:

1. Connections are provided for extracting information from the DCU to operate other electronic devices. Four prongs are added to the DCU plug and each is attached to the right-hand plate of one of the four binaries through a 1.2 megohm resistor. These additions appear in Figure 1.

2 The connection to the DCU chassis at one of the pins of the DCU plug is removed. This change permits the introduction of a negative supply voltage at this pin. The voltages at specific points within the Model 705AG when used as a part of the instrument described in this booklet appear in Figure 1.

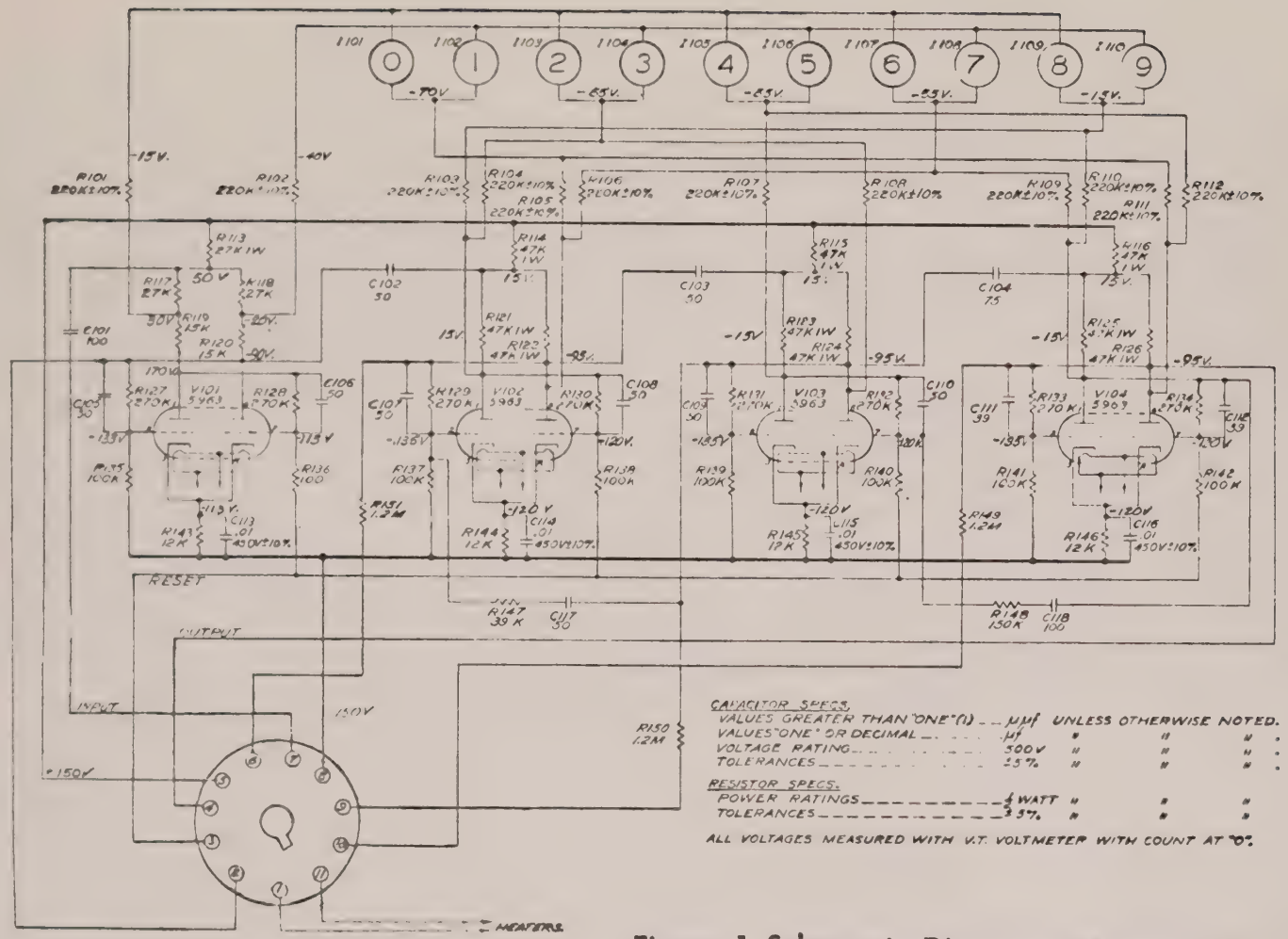


Figure 1 Schematic Diagram, Model 705AG

INSTRUCTION
MANUAL

Model 707AG
DECIMAL COUNTING UNIT

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
20 November 1954

The Model 707AG Decimal Counting Unit is simply a Model 707AF DCU with the connection to the DCU chassis at pin 8 of the DCU plug removed. This change permits the introduction of a negative supply voltage at this pin. The voltages at specific points within the Model 707AG when used as a part of the instrument described in this booklet appear in Figure 1.

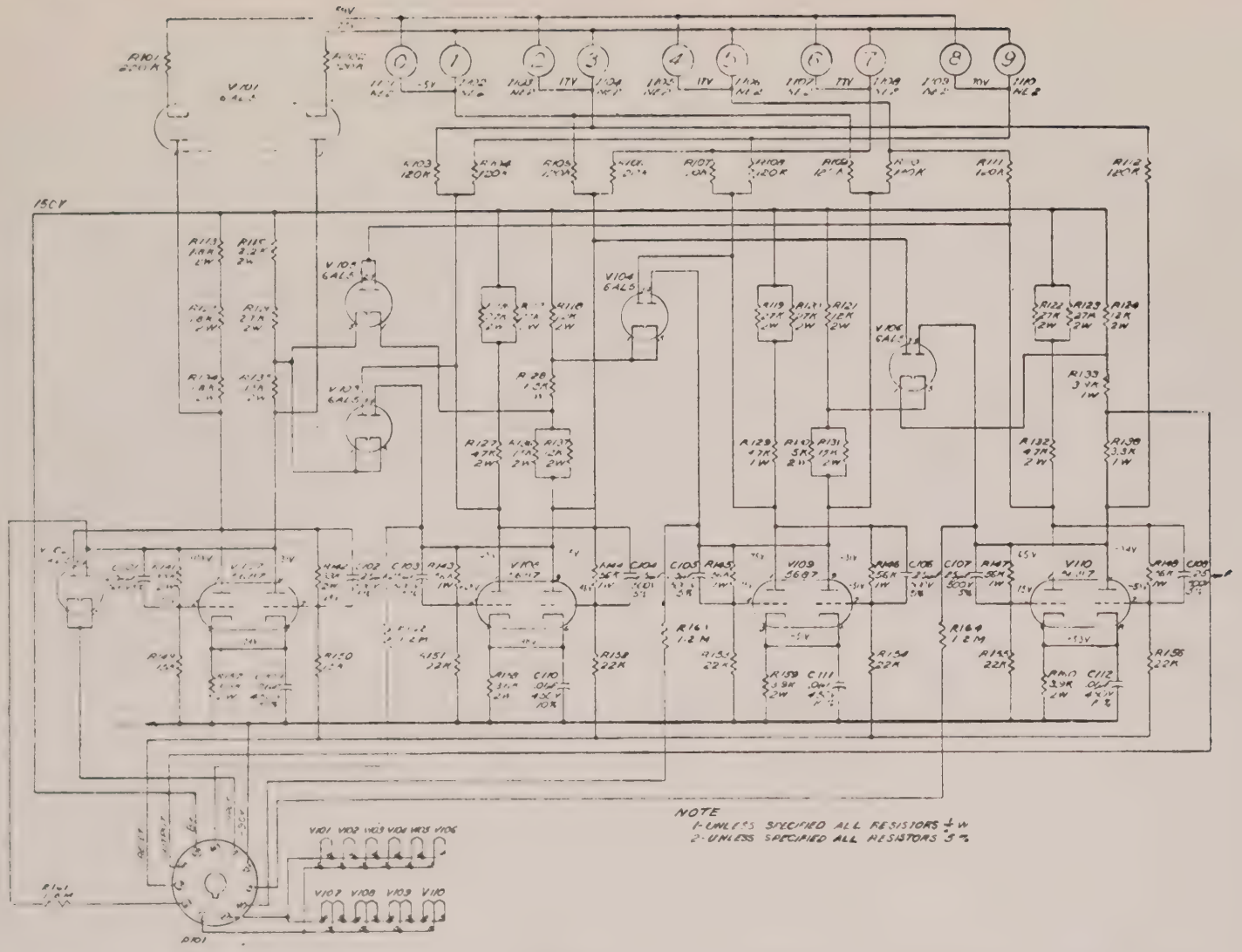


FIGURE 1 SCHEMATIC DIAGRAM, MODEL 707AG

INSTRUCTION
MANUAL

Appendix B

Model 707AF
Decimal Counting Unit

BERKELEY division of
Beckman Instruments, Inc.

Richmond 4, California
15 December 1953

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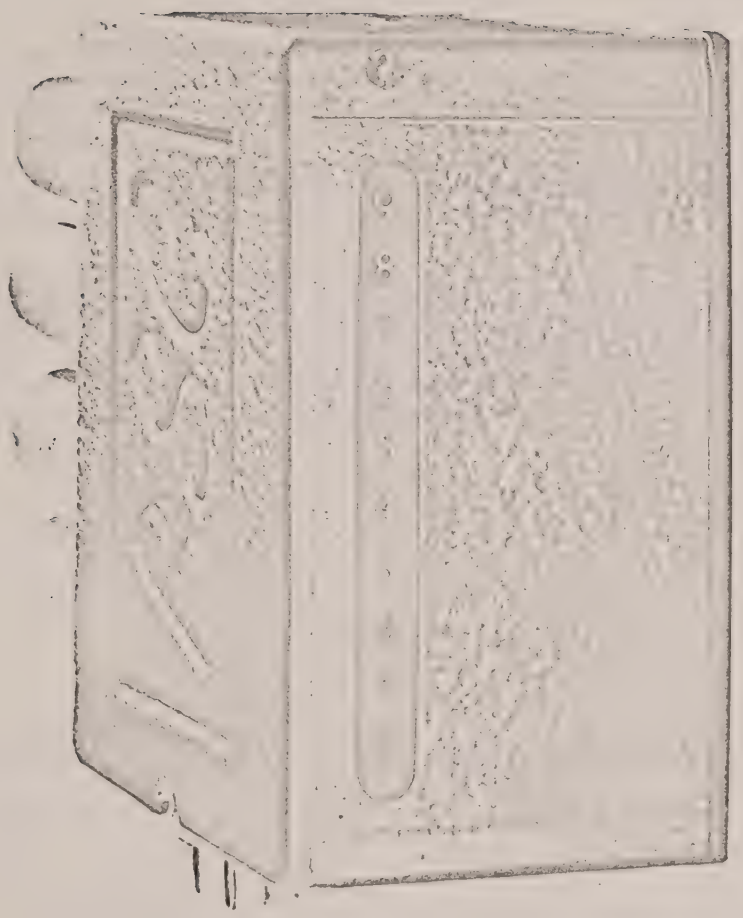

Figure 1 Model 707AF Decimal Counting Unit

Section 1
INTRODUCTION

The Model 707AF Decimal Counting Unit is direct-reading, plug-in electronic counter. The number of counts received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. The maximum repetition rate of the input is one million counts per second. For random pulses the resolution is 0.8 microseconds.

The Model 707AF will drive Models 705A and 705AF which counts at 100,000 cycles per second. Models 705A and 705AF will drive Models 700A and 700AF which count at 40,000 counts per second. These units may be cascaded to form a counter whose total capacity depends only on the number of DCU's used. Thus, six units will count to 999,999, resetting to 000,000 on the 1,000,000th pulse.

Specifications

Count Indication	Direct reading decimal presentation
Power Requirements	Heater: 6.3V at 5.4A near ground potential Plates: 175 to 260 volts (nominal 225 at 60 ma)
Input Requirements Recommended	Negative pulse 150 volt peak amplitude
Rise Time	Less than 0.15 μsec.
Duration	0.4 μsec.
Output Characteristics	Designed to drive a 705A or 705AF.
Resolution of Paried Pulses	0.8 μseconds
Reset to Zero	Instantaneous through opening of grid return
Maximum Counting Rate	1,000,000 cps
Construction	Plug-in unit, 11-pin socket
Dimensions	3" x 5-5/8" x 5-3/8"
Weight	1-1/2 pounds
Tubes	Six 6AL5's and four 5687's

Section 2
OPERATION

Installation

Normally, Decimal Counting Units are installed in Berkeley instruments. No special instructions are necessary. For unusual installations, we invite your inquiry.

The reset pin (pin #3 on the 11-pin plug should be connected to ground through a normally-closed switch or relay contacts. To reset the unit open the contacts momentarily. Care must be taken to avoid coupling voltages surges into the input or power supply circuits.

Operation

Plate	175 to 260 volts (nominal 225 at 60ma)
Filament	6.3 volts at 5.4 amps near ground potential

Input requirements:

For optimum operation, drive the unit from a pentode, such as a 6AS6 or 6AU6, whose plate is directly connected to the input of the unit, thereby using the first stage of the DCU as the pentode plate load. A negative transient of 150 volts peak amplitude negative with respect to B+ is required to trigger the unit. The rise time should be less than 0.15 microseconds, and the duration at least 0.4 microseconds. When the unit is powered by an unregulated supply, the drive amplitude should be proportional to the supply. If condenser coupling is used to the input diode, the cathodes should be connected through a resistor to B+.

Output requirements:

The output is a rectangular waveform as shown in Figure 4G. It is represented at the output terminal as a change in direct current voltage level. Between counts of "0" to "4" it is 90 volts; "4" to "6", 150 volts, and "6" to "9" 180 volts. The load imposed on a unit must not be more than 100,000 ohms to ground, or a 5,000 ohm resistor with a 100 $\mu\mu$f capacitor to ground.

Regardless of the number of units, all may be set back to zero by momentarily opening the ground connection to a common line connected to pin 3 of the 11-pin socket. Care must be taken to avoid coupling voltage surges into the input or power supply circuits, otherwise they may not remain at zero upon reconnecting to ground. If a pulse is used to reset the unit, it should be 50 volts positive and at least 5 microseconds in duration.

Section 3
THEORY OF OPERATION

The basic circuit of the Model 707AF is a modification of the Eccles-Jordan Trigger Circuit having two stable states, known as a binary. The type of binary used is shown in Figure 2. It is a two-stage amplifier with the output of the second stage connected to the input of the first. With no input, the loop gain is less than one, and the circuit is in one of its two stable states, i.e., either V1 conducting and V2 cut-off, or V1 cut-off and V2 conducting. The circuit is triggered from one state to the other by making the loop gain greater than one.

The binary is coupled to a single trigger source through the coupling diodes V3 and V4. If the input signal voltage has a steady value equal to B+, either diode is conducting, since the potential of the plates of the diodes is either less than or equal to that of their cathodes. Assume that V2 is conducting and V1 is cut-off. If a negative pulse is applied to the input, V3 will conduct. Since its resistance is small compared to that of R1, the plate of V1 is driven negative. This drives the grid of V2 negative through the crossover network R6, R7, C2 and the grid-to-ground capacity of V2.

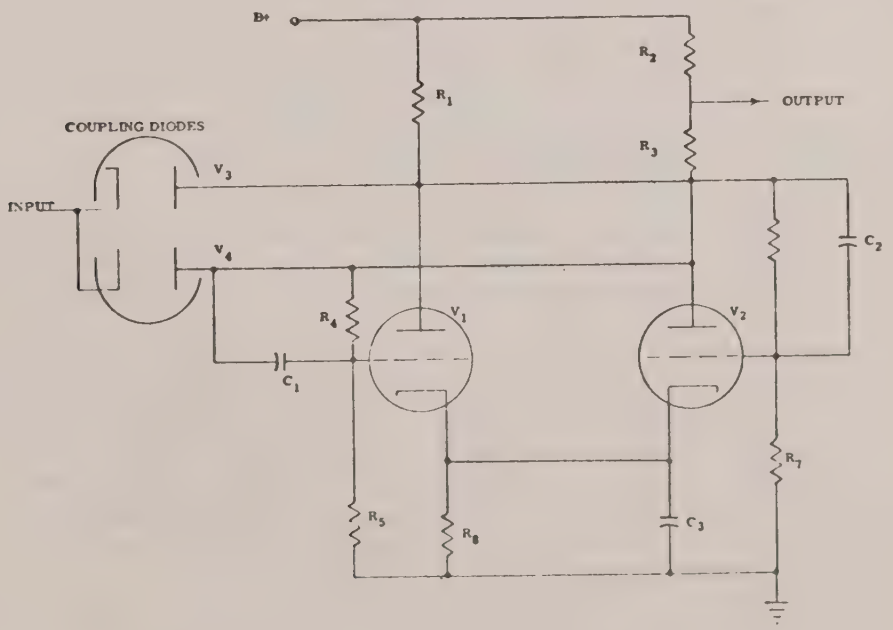

Figure 2 Basic Circuits

When the input pulse amplitude is sufficient, the loop gain of the binary becomes greater than one and it is triggered to its other stable state, i.e., V1 conducting and V2 cut-off. The next input causes the binary to return to its original state. It is seen that the binary is made to cycle once for two input triggers and is a scale-of-2. A counter having a scale of any power of two can be obtained by connecting binaries in cascade.

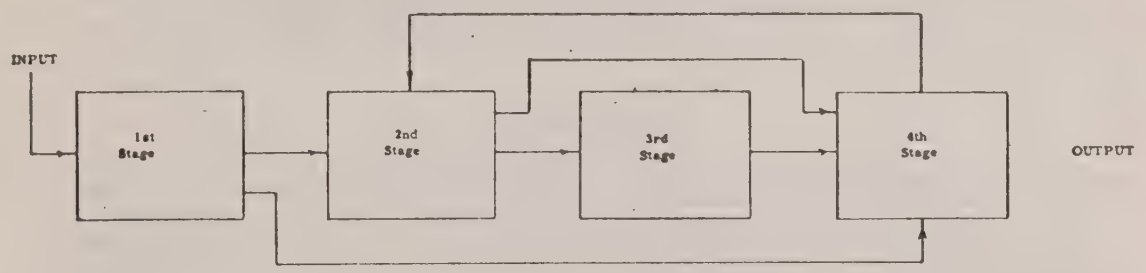

Figure 3 Functional Diagram 707AF

In the Model 707AF, four binaries are connected in cascade, making a scale-of-16, which is permuted to a scale-of-10 by three diodes (see Figure 3). Two of these diodes are used as clamps and the third for coupling. The coupling diode is used to drive the fourth stage in one direction from the first stage. The diode clamps hold the off stage of a given binary to a voltage low enough that it cannot be driven by the preceeding stage. In the reset position, one diode clamp holds the fourth stage so that it cannot be driven by the coupling diode form the first stage. On the count of 2, the second stage is driven by the first stage, releasing the clamp on the fourth stage, and the second stage is then clamped by another diode from the fourth stage, so that it cannot be driven by the first stage. On the count of 4, the first stage drives the fourth stage releasing the clamp on the second stage. The state of the four binaries at this point is the same as the count of 10 in a scale-of-16. The clamping and driving the fourth stage from the first has the effect of adding six additional counts on the fourth input pulse. The scaler counts as a conventional binary counter for the remaining six input pulses. The adding of six counts on the fourth input pulse converts the scale-of-16 to a scale-of-10.. Decimal indication is obtained by connecting ten neon lamps to the unit through a resistor matrix (see Figure 6).

Section 4
MAINTENANCE

When a Decimal Counting Unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determined whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Since the counting unit is usually the indicating device of a larger instrument, faulty operation is often ascribed to it when the symptoms of external faults are displayed.

Troubleshooting

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Typical waveforms are shown in Figure 4. By comparing these with the waveforms from a defective unit, the faulty stage can be quickly detected. Table 2 lists the voltages and resistances between tube socket connections and ground so that, in conjunction with the schematics and parts location diagrams, all information necessary to maintain the equipment in proper working order is available. It should be remembered that the values given are nominal, and considerable variations may be encountered owing to various line voltage conditions and component tolerances.

Circuit drawings and parts location diagrams will be found at the rear of the manual. The voltages shown were obtained with a vacuum tube voltmeter, a supply voltage of 225 volts, and measured between ground and the point indicated. The unit must be reset to zero to obtain the values shown.

3. Four stable states per cycle.	(a) Count is 6789 (resets to 6). V109 defective (b) Count is $\frac{01}{45}$ 45 - $\frac{01}{45}$45 (resets to $\frac{0}{4}$). V109 defective. (c) Count is $\frac{0}{4}$ 145 - $\frac{0}{4}$ 145 (resets to 0). The first cycle after reset is 012345 and the remaining ones are $\frac{0}{4}$ 145). V104 defective. (d) Count is 6789 (resets to 0). The first cycle after reset is 0123456789 and the remaining ones are 6789). V104 defective.
4. Eight stable states per cycle, that is, the pattern of lighting is repeated for every eight input pulses. It is possible to have more than one lamp ON for one or more of these states if there are eight distinct states per cycle.	(a) Count is $\frac{01}{45}$456789 - $\frac{01}{45}$456789 (resets to "0" but "4" on while reset switch is open. V110 defective. (b) Count is 01456789-01456789 (reset to "0"). V105 defective. (c) Count is 01236789-01236789 (reset to "0"). V106 defective. (d) Count is $\frac{01}{45}$456789 (reset to "0"). The first cycle after reset is 0123456789 and the remaining ones are $\frac{01}{45}$456789. V106 defective.
5. More than ten stable states per cycle as observed on an oscilloscope.	(a) Input pulse amplitude too small. (b) Marginal tube in any stage.
6. Unit scales correctly as observed on an Oscilloscope, but lighting pattern is 13579 at high frequency and at a slow repetition rate. (No light on reset).	(a) V101 defective.
7. Unit scales correctly as observed on an oscilloscope but lighting pattern is 02468 at high frequency and at a slow repetition rate (resets at 0).	(a) V101 defective.

Table 2

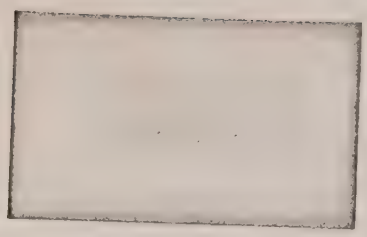
MODEL 707AF - VOLTAGES & RESISTANCES

Tube	Pin No.	D.C. Voltage to Ground	Resistance to Ground (in ohms)*
V107	1	200	14K
	2	33	12K
	3, 6	60	3.3K
	4, 5, 8	Filaments	
	7	60	12K
	9	110	14K
	1	138	20K
	2	20	18K
	3, 6	37	3.6K
	4, 5, 8	Filaments	
	7	38	18K
	9	68	21K
V109	1	150	21K
	2	15	18K
	3, 6	36	3.9K
	4, 5, 8	Filaments	
	7	37	21K
	9	55	21K
V110	1	140	22K
	2	15	18K
	3, 6	35	3.9K
	4, 5, 8	Filaments	
	7	35	18K
	9	55	22K

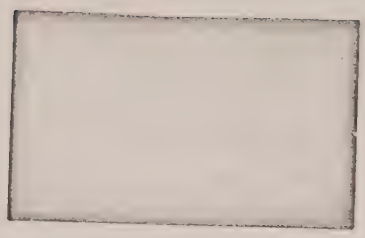
*Note: B+225V
Pins 3 & 8 tied together

NOTE

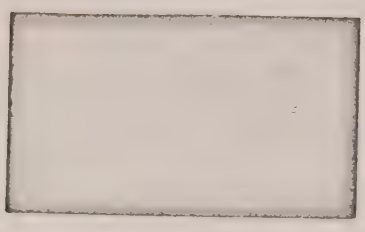
The following waveforms were photographed with a 4 x 5 Grover View camer at f4.5 and one-half second, with a Model 511AD Tektronix Oscilloscope.



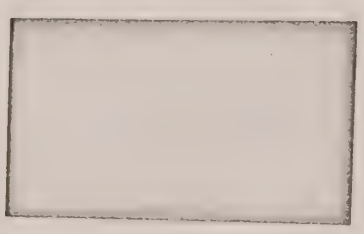
A. First stage, Pin 9, V107, UVL + 205, LVL + 110, frequency 500Kc.



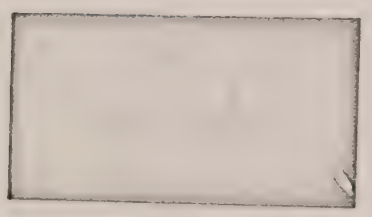
B. Same waveform blanked.



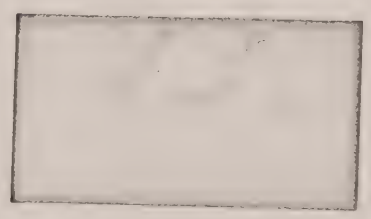
C. Second stage, Pin 9, V108, UVL + 180, LVL + 65, step at + 145, frequency 500Kc.



D. Same waveform blanked.



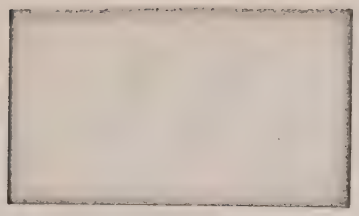
E. Third stage, Pin 9, V109, UVL + 180, LVL + 65, step at + 145, frequency 500Kc.



F. Same waveform blanked.

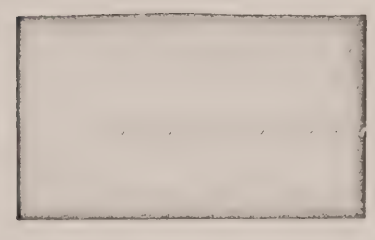
Note: UVL = upper voltage level
LVL = lower voltage level

Figure 4 Typical Waveshapes

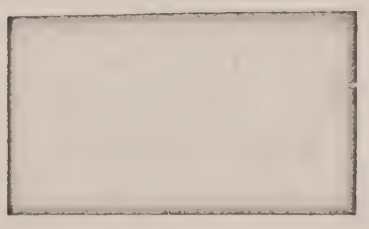


G. Fourth stage, Pin 9, V110, UVL + 180, LVL + 65, step at + 145, frequency 500Kc.

H. Same waveform blanked.

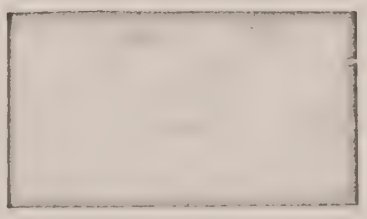


I. First stage, Pin 9, V107, UVL + 205, LVL + 110, frequency 100Kc, (blanked).

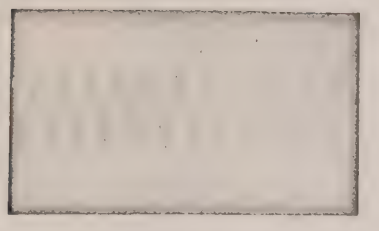


J. Second stage, Pin 9, V108, UVL + 180, LVL + 65, step at + 145, frequency 100Kc (blanked).

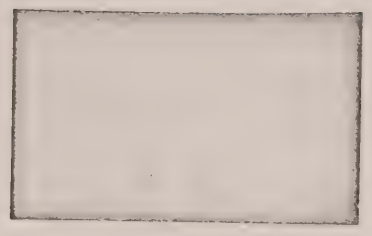
K. Third stage, Pin 9, V109, UVL + 180, UVL + 65, step at + 145, frequency 100Kc, (blanked)



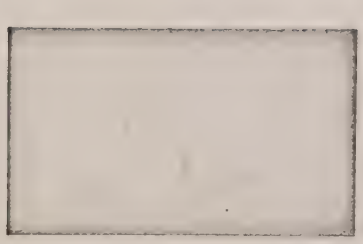
L. Fourth stage, Pin 9, V110, UVL + 180, UVL + 65, step at + 145, frequency 100 Kc., (blanked).



M. First stage, Pin 9, V107, UVL + 190, LVL + 105, frequency 1 Mc. (blanked).



N. Second stage, Pin 9, V108, UVL + 180, LVL + 65, step at + 145, frequency 1 Mc. (blanked).



O. Third stage, Pin 9, V109, UVL + 180, LVL + 65, step at + 145, frequency 1 Mc. (blanked).

P. Fourth stage, Pin 9, V110, UVL + 180, LVL + 65, step at + 145, frequency 1 Mc. (blanked).

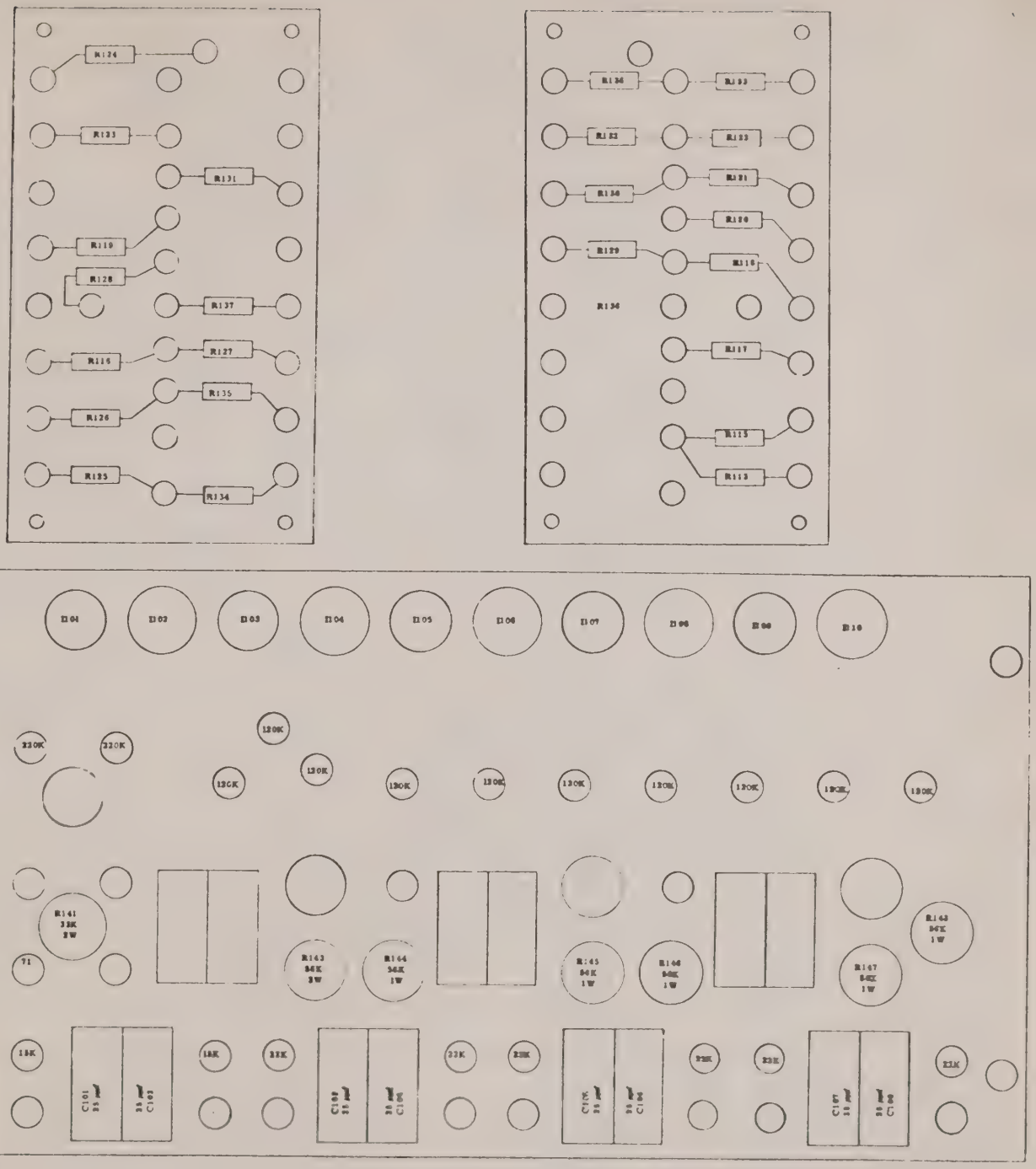


FIGURE 5 PARTS LAYOUT, MODEL 707AF.

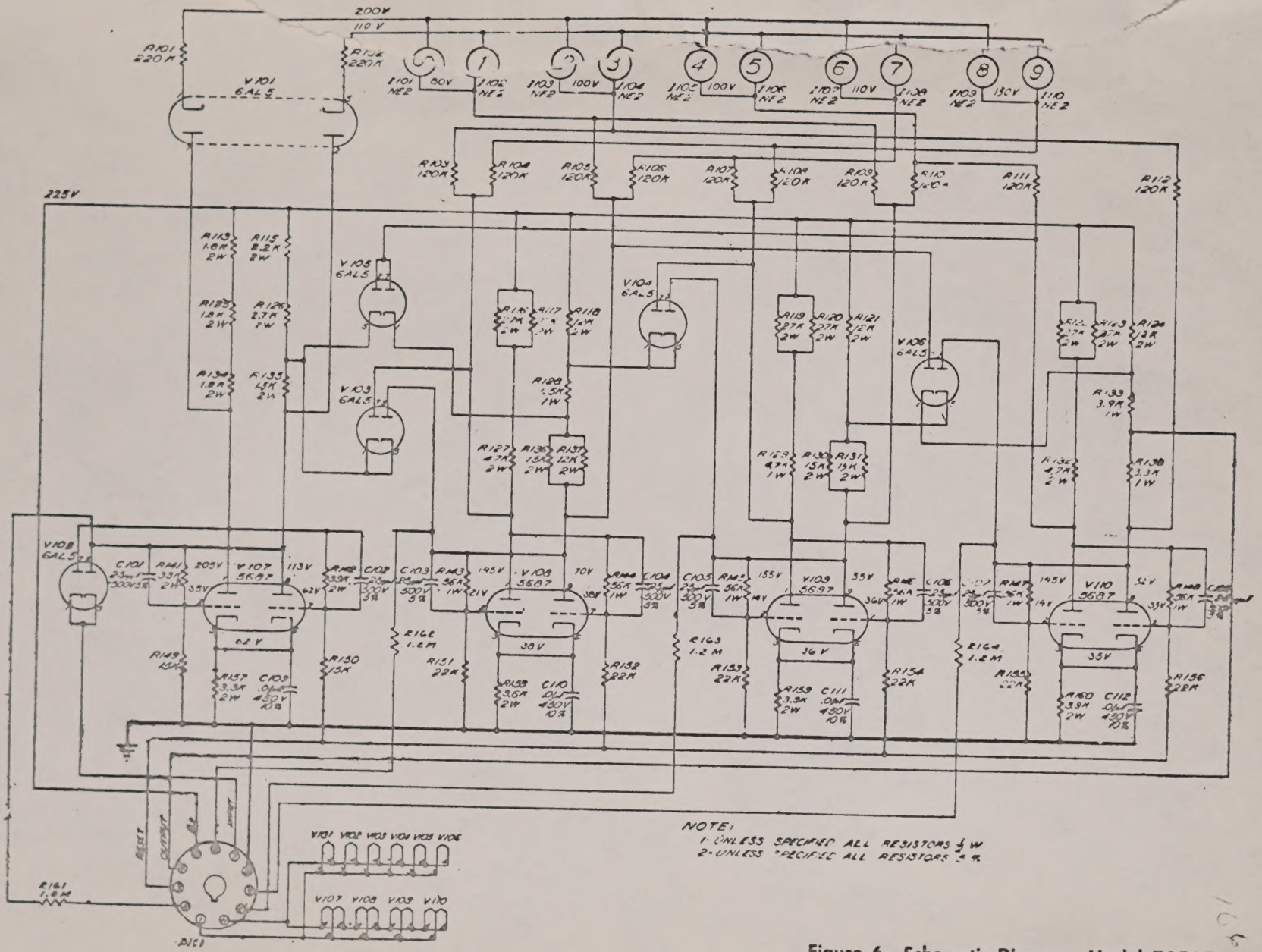


Figure 6 Schematic Diagram, Model 707AF

ACCOPRESS BINDER

BF 250 EMB

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